SPECIFICATIONS FOR

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SPECIFICATIONS FOR STREET ROADWAY PAVEMENTS

WITH INSTRUCTIONS TO
INSPECTORS ON STREET PAVING WORK

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SECOND EDITION
REVISED, ENLARGED AND ENTIRELY RESET

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PREFACE TO SECOND EDITION

In offering to the public a new edition of "Specifications for Street Roadway Pavements" the author has taken advantage of the opportunity to revise and expand somewhat the matter in the original edition and to add thereto Instructions for Inspectors on pavement work.

Since the publication of the original pamphlet in 1907 no little advance has been made in the design and construction of street pavements and the framing of specifications for that work. Aside from the personal study and efforts of individual engineers, the Association for Standardizing Paving Specifications, organized in the latter part of 1909, has held four important conventions, devoted to the improvement and standardization of specifications for street pavements, and its able standing Committees have devoted much time and thought to the subject. The American Society of Municipal Improvements has also devoted much attention to the subject and has adopted standard specifications for most of the common kinds of pavement. Other organizations have been working along the same lines.

Under these circumstances it might be thought that there is no longer any pressing need for the continuance of individual efforts in this field, and it has been with some hesitation that the author has returned to it. Without venturing to criticise the work done by these public organizations it has seemed to the author that there is yet room for individual work in this field, if for no other reason than that there still remain quite divergent views not only as to the substance, but as to the form, scope and phraseology of specifications, and contributions based upon some knowledge and experience in street pavement may not be without value in reaching final conclusions.

As might be expected experience and observation during the past five years have, in a number of particulars, modified the author's opinions and shown where the original specifications offered might be improved and enlarged, so that while, in the main, those now offered follow the original text, the reader will find not a few changes.

There has also been added specifications for two comparatively new kinds of roadway pavement that have merited attention, and for concrete sidewalk and concrete combined curb and gutter.

So far as the author is aware there has not been printed, in America at least, any complete and comprehensive code of instructions for pavement inspectors, though there appears to be a demand, as there certainly is a need, for something of the kind.

Having been asked about a year since to prepare such a set of instructions for the use of one American city, the author has rewritten parts of them in a more general form, and they are printed (with the permission of the engineer for whom they were written) as Part II of this edition. While they would need some revision and modification to meet the conditions and special specification provisions in any particular city, it is thought they may be useful in at least suggesting the points to be covered.

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INTRODUCTORY

In addition to their value as memoranda and aids in preparing specifications for a particular project, carefully prepared general specifications, embodying the latest approved practice, sometimes supply the most useful and acceptable brief treatises upon any particular branch of engineering work. It has been partly with this thought in mind that the following set of specifications for standard street pavements has been prepared and is now offered to city engineers and municipal authorities.

To widen their range and increase their usefulness, copious foot notes have been added, referring to alternative requirements and methods of construction, and giving some of the reasons for the preference or adoption of the construction called for in the specifications. It is recognized that in a good many matters of detail embraced in these specifications there is difference of opinion among able engineers, many of whom are at least as competent as the writer to determine what is best. They are not offered in a dogmatic spirit, or with the hope that all the provisions found therein will be accepted. If they shall be of some assistance in bringing about correct standards for such specifications, their preparation will have been justified.

Theoretically, three general classes of engineering specifications may be noted. In the first, the aim of the engineer is to specify the end or result that it is desired to secure, leaving the contractor free to originate and follow the methods by which these results are to be attained. In the second the engineer aims to secure the desired end by specifying in detail the materials and the methods which in his opinion will accomplish the purpose, he himself assuming responsibility for the results. Either of these two classes of specifications is permissible, and the engineer may choose the one which in his opinion seems best adapted to the character of the work to be done, and the conditions under which it must be prosecuted.

In the third class of specifications, met with more frequently than they should be, the engineer undertakes to prescribe not only the character of the materials to be used and the methods to be pursued, but also the results to be attained. The position thus assumed is illogical, and often unreasonable, and may lead to com-

plications between the engineer and the contractor. If a contractor be required to turn out a product which shall conform to certain standards, he may properly be given much, if not full latitude, as to how the stipulated results shall be secured, and may be held fully responsible for the outcome; if on the other hand the engineer chooses to specify with more or less minuteness the character of the materials to be used and the methods of construction to be followed, and enforces compliance therewith, it seems fair and just that he should assume responsibility for the results produced, and therefore unfair to hold the contractor to responsibility for consequences arising from the use of materials and methods which he was allowed no choice or latitude in selecting.

In street paving work, of well-known and standard character, the second class of specifications seems preferable for a number of reasons, the leading one being that the time required to develop the good or bad quality of the work must usually extend over a considerable number of years, and the conditions to which the pavement may be subjected in the meantime are likely to vary so widely that it may be very difficult, if not impossible, to prescribe a satisfactory standard of service and endurance. Disputes are therefore liable to arise between the municipality and the contractor as to the latter's liability, or conditions may make it difficult or impossible to hold the contractor to strict account for that liability.

It is believed that in the present state of the art it is entirely practicable to so frame specifications for the materials to be used and the methods to be followed in the construction of standard street pavements, and to so enforce compliance therewith, that the engineer and the municipality may safely assume responsibility for the quality of the work produced. While it may be true that local conditions sometimes make it very difficult to enforce compliance with specifications, the same conditions are likely to make it at least equally difficult to secure effective responsibility on the part of the contractor for any long-period guarantee of the work done by him; and the contractor who negligently or purposely violates the specifications during construction is not likely to be more faithful or scrupulous in living up to any guarantees he may make with regard to the future, even where the terms and conditions of such guarantees may be clearly defined and indisputable. The writer has discussed the subject of time guarantees as applied to street pavements pretty fully in his book, "Municipal Public Works," and the above brief statement seems all that is necessary here.

In conformity with this view of the matter, the following specifications aim to set out as definitely and clearly as practicable the requirements for the construction of good pavements of the several standard kinds, and it is assumed that the engineer will be able to, and will enforce them.

It is, however, not infrequently the case that the engineer will be called upon to prepare specifications for new, or patented, or proprietary pavements advocated by their promoters, the value or usefulness of which have not been sufficiently established by experience, and for which the data for detailed, definite specifications are not yet available.

In such cases the wisest course to follow is to confine the precise specifications to the general or standard parts of the work, while stipulating only the *results to be attained* with regard to those features of the work that are proprietary or questionable, thus placing upon the promoter or his contractors full responsibility for such results as are promised of guaranteed. This applies to new or comparatively untried materials or processes, whether patented or not.

A proposed form of general specifications to cover such cases is offered herein.

It is usually unwise to adopt or to incorporate in the municipal specifications those prepared or offered by the promoter or patentee, which are often brief, incomplete, and indefinite, and are sometimes carefully, and even cunningly, drawn to evade final responsibility.

No attempt has been made to submit specifications for proprietary or patented pavements, or those composed wholly or in part of materials which are patented or protected by trade-marks. The owners or contractors engaged in constructing these pavements, often, if not usually, claim the right to dictate the material parts of the specifications under which such work shall be done, and the municipal engineer who is called upon to construct such pavements, must, in each case, determine whether the specifications offered are adequate and satisfactory, and the extent to which he feels justified in accepting responsibility for the results. Naturally, the contractor or promoter, even if competent to prepare specifications, cannot be expected to bind himself within closer limits than he thinks necessary to secure the work. In many such cases the form of general specifications for "untried or experimental pavements" given herein might appropriately be used.

The engineer is, in common with all men, fallible, and he can hardly hope, in the preparation of specifications, to make them

perfect; to cover every item and particular; or to escape some ambiguities of expression, and some degree of indefiniteness. The writer can only claim that he has aimed, in the light of a considerable experience, to set out as fully and definitely as practicable the requirements for the proper construction of high-class street pavements, and has endeavored to avoid loose or obscure terms and expressions. The ideal specification is one that furnishes a wholly sufficient guide to the accomplishment of the desired purpose; that provides for every possible contingency which may arise, and is couched in language which not only means exactly what it was intended to mean, but is incapable of any other interpretation. It is needless to say that no example of such a perfect specification can be instanced as a model.

It has been the aim to make these specifications fair and just to the contractor; that is, to require of him no impracticable or indefinite service, or the assumption by him of risks other than those fairly involved in the business conduct of the work.

If the plans and specifications for any work which a contractor bids upon are so full, specific, and clear, that he may know exactly what he will be expected to do, and if they do not require him to assume unusual chances and risks, he may intelligently name prices which he believes will compensate him for the service. Having done so, his proposal having been accepted, and a contract entered into accordingly, the engineer and the municipality have a right both in law and equity to demand that he will do exactly and fully what he has contracted to do. No excuses on his part can be valid and none should be accepted. He may in all fairness and justness be required to "toe the mark" strictly. To the neglect to recognize and enforce these principles is chargeable the greater part of the poor and unsatisfactory work so common in street pavement work in our cities. Unexpected contingencies may, of course, arise where some changes and concessions may be proper and just, but these should be, and usually are, very rare. On the other hand, sweeping general clauses in contracts and specifications intended to catch the contractor "goin' or comin'," unnecessarily stringent stipulations which were never intended to be strictly enforced, but were put into the specifications with the idea that they would help hold the contractor up to a high standard, and "one-sided" contracts intended to give the municipality an unfair advantage over the contractor, are as inadvisable in policy as they are wrong in principle. Nothing should be put in a specification that is not clearly essential to secure

the results aimed at, and, this having been done, every requirement should be enforced. The existence in specifications of requirements that are not intended to be enforced, gives the contractor a pretext for neglecting others that may be important.

In these specifications will be found a number of details that are often not regarded as important and which, when found in paving specifications, the contractor is frequently allowed to ignore. In the writer's opinion, based upon his experience in street paving, every one of these requirements is essential to the production of high-class work, which, it is hardly necessary to argue, is, in the end, the most economical work from the standpoint of the municipality.

It may be argued that the adoption and enforcement of these specifications would have the effect of raising prices. In many cases this would doubtless prove true. Contractors are entitled to a fair and reasonable compensation for their services. It is admitted that in some cities the prevailing prices for some kinds of pavements are below the actual cost of the work if it were done in a proper manner, conforming strictly to the specifications. Illogical as it undoubtedly is, the low price at which work is taken is sometimes considered a sufficient reason for accepting work below standard. The consequence is that bidders not only count upon concessions and lax enforcement of the specifications, but bid lower and lower, expecting that further concessions will enable them to get out with an undeserved profit. This is one of the most serious evils in the paving business to-day, and the highest public interests demand a thorough reform. Low first cost, desirable as it may be, is the poorest economy if it be secured at the sacrifice of the quality of the work. If one pavement costs twenty per cent. more than another, but renders forty per cent. more service, it is obviously the cheaper of the two.

Contractors are prone to contend that this or that provision in a specification is unusual, unnecessary or unfair. In dealing with them the engineer should bear in mind that no requirement of a specification that is clearly and definitely stated, so that the bidder may understand exactly what it means and what he will be expected to do, and may frame his prices accordingly, can be unreasonable or unfair to the contractor. Unusual or unnecessary requirements may result in unwarrantably increasing the cost of the work, and this may raise a question between the engineer and the municipality employing him, but it can furnish no occasion for questions of fairness or unfairness between the contractor and the engineer.

The relations that should exist between the contractee and the contractor, and the attitude of the engineer toward the contractor have been widely discussed and are quite well understood from both the ethical and legal standpoint.

It is well to bear in mind that when a contract is duly entered into, both the parties thereto are equal before the law. Neither can impose upon the other terms or conditions that are not clearly included in or to be fairly inferred from the contract itself. The assumption that either party has superior or extra rights not expressed or to be fairly inferred from the written agreement, or in accordance with the established rulings of the courts, is wholly without warrant. The smallest contractor is, in this respect, upon an equal footing with the largest city government for which he may undertake to do contract work. It is not infrequently the case that the city assumes a superior and dictatorial attitude not in harmony with these principles, and it is too common for the contractor to seek to evade or to escape from clear contractural obligations. In neither case is the action warranted by fairness, justice, or law.

It should be needless to say that the attitude of the engineer toward the contractor should be one of unyielding and uncompromising requirement that the contract and specifications shall be fully and faithfully complied with, but at the same time one of absolute fairness and even helpfulness to the contractor. The ideal relation, which should be more commonly attainable than it appears to be, is that of helpful cooperation to bring about the results the contract and specifications were intended to secure.

In line with the principles here outlined some observations upon the preparation of contracts and specifications are appropriate.

It is the general practice to include in and make a part of "The Contract" (herein for convenience called The General Contract) all the various documents that are supposed to relate directly to the transaction as a whole. The separate parts of such a general contract may vary in number or character, but the principal ones are the following:

1. The advertisement for proposals.
2. Instructions to bidders.
3. The proposal submitted.
4. The contract proper.
5. The specifications.

Each of these should be drawn to cover fully and clearly its appropriate purpose or function but *nothing more.* It is not unusual

to find, even in the instructions to bidders, stipulations that properly belong in the contract or specifications, and it is quite common to find in the contract proper a lot of matter that properly belongs in the specifications only. In such cases there is liable to be more or less confusion as to the actual meaning or requirements of the general contract as a whole, which may lead to serious misunderstandings and complications between the parties thereto. The several documents composing the general contract are likely to be prepared by different persons, looking at the transaction from different points of view, and often not wholly familiar with the scope, intent and language of the other documents. There is therefore a possibility, at least, of indefinite, if not of conflicting expressions which are open to different interpretations, particularly in the light of special or unexpected conditions that may arise during the progress of the work or the settlement therefor. It would tend to eliminate or avoid the possibility of such complications if each of the several documents confined itself strictly to its appropriate function in the general contract.

Advertisements for proposals may be divided into two general classes. The one is brief in form and substance, simply stating that proposals for a certain named work will be received at a stated place and time, and referring those interested to documents on file at a stated place for all further information. This is the general form adopted by the United States War Department for the many projects carried out by contract under its direction. A sample advertisement taken from a current technical journal is as follows;

> TREASURY DEPARTMENT, OFFICE OF the Supervising Architect, Washington, D. C., October 10, 1912. Sealed Proposals will be received at this office until 3 o'clock p. m. on the 1st day of November, 1912, and then opened, for an electric passenger elevator in the United States post office, Bellingham, Wash., in accordance with the drawing and specification, copies of which may be had at this office at the discretion of the Supervising Architect. OSCAR WENDEROTH, Supervising Architect.

The other general class of advertisement, very commonly used by municipal corporations, is much longer and more elaborate, giving a condensed statement of the character of the work to be done, the conditions under which proposals are invited and will be received, and a schedule of the quantities of work involved, together

with other particulars. A typical example of such an advertisement, taken from the same periodical, is here given:

PUMPING MACHINERY—ROSELAND PUMPING STATION

DEPARTMENT OF PUBLIC WORKS

CHICAGO, ILL., October 2, 1912.

Sealed proposals will be received by the City of Chicago until 11 A. M. Wednesday, October 30, 1912, at Room 406, City Hall, for furnishing and erecting at Roseland Pumping Station one vertical triple expansion crank and fly wheel pumping engine of a capacity of twenty-five million (25,000,000) gallons per day against a normal head of one hundred and forty feet (140'). This proposal also includes the dismantling of a similar engine now at Lake View Pumping Station, transporting and erecting it at Roseland Pumping Station, together with the furnishing and erection of certain auxiliaries and appurtenances, according to plans and specifications on file in the office of the Department of Public Works of said city, Room 406, City Hall.

Proposals must be made out upon blanks furnished at said office, and be addressed to said Department, indorsed "Proposals for Pumping Machinery, Roseland Pumping Station," and be accompanied with Five Thousand ($5,000) Dollars in money or a certified check for the same amount on some responsible bank located and doing business in the City of Chicago and made payable to the order of the Commissioner of Public Works.

The Commissioner of Public Works reserves the right to reject any or all bids. A deposit of One Hundred Dollars ($100) will be required to insure safe return of the plans.

No proposal will be considered unless the party offering it shall furnish evidence satisfactory to the Commissioner of Public Works of his ability, and that he has the necessary facilities together with sufficient pecuniary resources to fulfill the conditions of the Contract and Specifications, provided such Contract should be awarded to him.

Companies or firms bidding will give the individual names as well as the name of the firm with their address.

L. E. McGANN,
Commissioner of Public Works.

Such advertisements as this may be required by statutes or ordinances, and in that case are, of course, proper and necessary. Even where not so required they may be considered advantageous, because they give prospective bidders more complete information as to the character and magnitude of the work, and may enable them to decide at once whether they care to pursue the matter further. But on the whole, the shorter form of advertisement, if permissible, seems preferable, because it refers the enquirer directly to the original and official sources of information, the forms to be used, the contract, specifications and estimated quantities of work, exactly as they will and must be presented to all bidders, and as they will appear in the subsequent stages of the transaction, and leaves, therefore, no room for possible confusion of statements between the advertisement and the other documents. Furthermore, the cost of the shorter form of advertisement is much less, and this is often a matter of some importance.

Instructions to bidders should be confined strictly to such information and directions as the bidder may need to properly and intelligently make up and submit his proposal in accordance with the requirements relating thereto. This should include primarily, a reference to the contract and specifications for all general and detailed information about the work to be done, but should carefully avoid any statements or language that might be construed to add to, take from, limit or modify the contract or specifications. Perhaps the briefest and best statement of what this document should or should not contain is that it should be so framed that, except as a matter of record, its office and usefulness should absolutely end with the award and signing of the contract.

No one who is not a lawyer can presume to say just what the contract proper should contain or cover, particularly as this may vary with the requirements of statutes and ordinances in force in a given city. It would seem logical and proper, however, to separate the special functions of contracts and specifications in such a way that each should cover a distinct field of its own, and be free from encroachment upon the proper domain of the other. With such a conception of the proper domain of each, one might safely say that the contract should undertake to set out only the legal and contractural relations of the parties thereto, and should refer to the plans and specifications for all detailed instructions as to the actual performance of the work and the results to be secured.

In the preparation of specifications for any public work the main

points to be kept in mind are fulness, definiteness, and exact expression. While brevity and conciseness are desirable qualities in any document, they should not be secured at the expense of completeness and precision of statement. Even the frequent repetition of words, phrases and sentences throughout a document, where it is necessary to avoid the possibility of misunderstanding or ambiguity, should be resorted to freely. Exact description and definition are more important than literary style, though they may often be successfully combined. Of course, it is not possible or necessary to go into minute detail with regard to every part of the work. Certain things may be safely assumed to be required by established practice or trade usage. If, for instance, it is specified that certain lumber shall be "dressed" this word has a well-understood meaning in the trade and it is unnecessary to stipulate how the dressing shall be done or its character or quality, though it may be necessary to say whether it is to be dressed on one or more sides.

The proper preparation of specifications for any work involves a clear, distinct and complete conception, determination and design of what is to be done; of the conditions that are likely to be met with in carrying it out; and of alternate plans that these conditions may necessitate. This may not always be possible, for the engineer is not omniscient. But careful study and maturity of design will enable him to avoid the great majority of such indefinite expressions as "or in such other manner as the engineer may direct," "in accordance with the instructions of the engineer," etc. A great many of the items to which such expressions are intended to and do apply in practice, could be definitely settled before the specifications are prepared and thus all uncertainty on the part of both engineer and contractor be avoided. To illustrate: specifications for block pavement commonly stipulate that the blocks shall be set in rows running at right angles to the axis of the street, except at street intersections, where the engineer may direct them to be laid at a different angle. There is usually no good reason why the engineer should not determine beforehand at which, if any, street intersections the general rule should be changed and so state in the specifications. These may be and usually are unimportant matters which may not much affect one way or the other the cost to the contractor. But they often prove otherwise, and the contractor is entitled to know when he submits his proposal just what he will be required to do. Of course it may develop during the progress of the work that changes from the original plan will become necessary, but these should

be provided for in some such definite and previously stipulated manner as outlined in Sect. 3 of the following specifications.

The practice of inserting, either in the specifications or the contract, a clause making the engineer judge and arbiter in any differences that may arise between the city and the contractor, and providing that his decision in all such cases shall be final, is as unwise as it is often illegal. Such clauses are based on the assumption that the engineer is a competent as well as a disinterested party in the transaction, an assumption that is usually wholly wrong, though to their honor it may be said that the confidence thus reposed in engineers is seldom abused. But the fact is that the engineer is never actually a disinterested party. He is employed and paid by the city to look after its interests, and is under no obligations to the contractor other than those named in the contract and specifications and his sense of justice, propriety and professional honor. He would be recreant to his duty if in all nicely balanced matters of doubt he did not espouse the side of his employer. Moreover, his personal interests are often involved. Having prepared the plans, specifications and estimates for the work, he is naturally and properly anxious that it shall be successful and that the cost shall not exceed that estimated. Under all these conditions it is hardly possible for any human being to be a wholly disinterested and unprejudiced judge. No broad-minded and conscientious engineer desires to be placed in such a difficult position, and it is as unfair as it is unwise and improper to require him to assume it.

There are, however, a number of matters of fact in reference to which it is proper and necessary to make the judgment and decision of the engineer controlling and final, unless it may be shown that his decision is clearly erroneous or affected by improper motives, or by fraud. Some one must necessarily be made the immediate and final judge as to whether the quality of materials and workmanship is in accordance with the requirements of the plans and specifications, and as to the quantity of work actually performed, and these duties and responsibilities are very properly placed upon the engineer.

It not infrequently occurs that specifications are not drawn as clearly as they should be in the matters of methods of measuring the work and of applying contract unit prices, and indefiniteness and carelessness in this regard are often a source of misunderstanding and dispute between the engineer and the contractor. It is a good practice, followed by many able engineers, after specifying

how a certain part of the work shall be done, to state how it shall be measured and paid for at the contract unit prices.

In many respects it is desirable that all the work to be done under contract should be quite fully itemized, and a unit price named for each kind of work. It is the custom in many cities to name only certain leading items of the work to be done under a paving contract, as for the pavement complete, furnishing and setting new curbing, redressing and resetting old curbing, and possibly a few other leading items, and to require that all necessary incidental work shall be done by the contractor without cost to the city; or, in other words, he must take this possible extra work into consideration in naming his unit prices for the leading items of the work. As the quantity of this incidental work is often not stated, and the contractor has no means of ascertaining it, he must guess, as intelligently as he may be able, how much he should add to his unit prices to cover its cost. If he is a prudent contractor he will be sure to add enough to prevent any possible loss on this account. In most cases the quantities of this incidental work can be determined and scheduled by the engineer with the more important items, and the contractor may be required to name unit prices for it. True, there are likely to develop during the progress of the work some items that could not be forseen or that were overlooked. In some cities such contingencies are provided for by a clause in the contract or specifications scheduling, by name, all the incidental minor items of work that experience has shown are likely to be met with in street-paving contracts, and naming fair unit prices which the contractor will be paid for each, should it occur. The contractor may then feel assured that however much the quantity of such incidental work may vary, he will receive compensation proportionate thereto, and he may name his prices for the main items with more confidence. Under such conditions it is reasonable to expect closer figures than he would be willing to name if an unknown quantity of incidental work for which no separate pay is provided had to be taken into consideration.

Sub-division of unit prices is also desirable in order that the engineer may be able to analyze and record the elements that make up the aggregate cost of the work. Thus, in the case of the construction of a new sheet-asphalt pavement it is common to ask for a single price for the pavement complete, including a five year guarantee. Now the work will consist of several distinct operations or kinds of work for each of which a separate price might be named:

1. The grading of the street and preparation of the sub-grade. The quantity of this work will vary on different streets and is best reckoned by the cubic yard of material excavated.

2. A price, either per cubic yard or per square yard for the concrete foundation.

3. A price per square yard for the asphalt pavement proper. This might, if desired, be sub-divided into separate prices for the base course and the surface course.

4. A price per square yard for guaranteeing the pavement for five years.

Such sub-division would, it is true, increase the work of final computation but if of no other value, the detailed costs would be a great aid to the engineer in estimating the reasonable cost of future work where the relative quantity of these detailed parts varied.

SPECIFICATIONS

For Grading and Paving, or Repaving

with .. .. Pavement
on a... .... Foundation, the Roadway
of ....
Street, from..... ....
to . ...
together with work incidental thereto.

GENERAL DESCRIPTION OF WORK

The work embraced in and to be done under this contract consists of grading the entire street from curb to curb between the limits named, including the removal or readjustment of the pavement now on the roadway, setting and resetting curbing, laying or relaying sidewalks where required, furnishing all new material and performing all the labor required for paving the roadway, together with all incidental work necessary to complete the whole in a proper manner, in accordance with the contract, the plans on

file in the office of the City Engineer, these Specifications and the instructions of the City Engineer, herein referred to as the Engineer, or his authorized agents.

REFERENCES

The numbered divisions of these specifications are herein designated as "sections," each being referred to by the number standing at its beginning. Where reference is herein made to any such section number it shall be considered equivalent to a quotation of that section.

The plans and drawings relating to this work, on file in the office of the City Engineer are designated as.....

.....

1. Authority.—Wherever, in these specifications, the words, the City, are used, they shall be understood to refer to the duly constituted municipal government of the city of.....

.....

or its authorized agents, acting within the authority specifically conferred upon them by the said municipal government.[1]

Wherever, in these specifications, the words, the Engineer, shall be used, they shall be understood to refer to the City Engineer of said city, or his deputies or assistants, acting within the authority conferred upon them by the City Engineer.

But no agent of the city shall have power to revoke, alter, enlarge or relax the stipulations or requirements of these specifications, except in so far as such authority may be specifically conferred in or by the specifications themselves, without the formal authorization so to do, conferred by the contract of which these specifications are a part, or by ordinance, resolution or other usual official action of the city.[2]

2. Interpretation.—In case of any actual or alleged disagreement or discrepancy between the contract, these specifications, and the plans for the work on file in the office of the Engineer, the language

[1] In specifications to be used in any particular city the official name of the city government, as the City Council, the Commissioners of Public Works, etc., should be used instead of this general designation.

[2] Such a proviso as this seems proper in justice to both the city engineer and the contractor; the former should not be held responsible for the acts of his assistants when they transcend the authority conferred upon them, and the latter should be put upon his guard with reference to requirements which he is not satisfied are sanctioned or approved by the city engineer.

and provisions of the contract shall take precedence and prevail; and the Engineer shall determine in each case whether the specifications or the plans shall be followed.

3. The Engineer shall have the right to make such changes in the plans and specifications of the work as he may deem necessary or desirable or to provide for unexpected conditions or contingencies that may develop at any time after the signing of the contract, or during the progress, or before the final acceptance of the work; provided that all such changes do not involve an aggregate increase or decrease in the cost of the work, as shown by his estimates, of more than ten (10) per cent. The contractor shall accept such changes when made, as a part of the original contract and specifications, subject to all the provisions and conditions thereof. But before any such changes shall become valid and before the contractor shall begin the particular work involved in such changes, the increased or decreased cost of the work by reason of such changes, above or below what it would have been under the original plans and specifications, shall be agreed upon in writing between the engineer and the contractor. And when the whole work, including such changes, shall have been completed and accepted by the engineer, the sum or sums so agreed upon shall be added to or deducted from the sum that would have been due the contractor if no such changes had been made.

4. **Quality of Material and Work.**—The judgment and decision of the Engineer as to whether the materials supplied and the work done under this contract comply with the requirements of these specifications, shall be conclusive and final. No material shall be used in the work until it has been examined and approved by the Engineer, or his authorized agents. All rejected material must be promptly removed from the work and replaced with that which is acceptable to the Engineer, and all improper or defective work must be corrected, and, if necessary, removed and reconstructed so as to comply with these specifications and the instructions of the Engineer.

In all matters of detail not specifically covered by the specifications the work shall be well and skillfully done in accordance with the best trade or art customs and standards for work of like character and purpose.

5. **Inspection.**—The Engineer may provide for the inspection, by assistants and inspectors under his direction, of all materials used and all work done under this contract. Such inspection may extend to all or any part of the work, and to the preparation or manufacture

of materials to be used, whether within the limits of the work on the street, or at any other place. The Engineer and his inspectors shall have free access to all parts of the work, including mines, quarries, manufactories, or other places where any part of the materials to be used is procured, manufactured or prepared. The Contractor shall furnish the Engineer all information relating to the work and the material therefor which the Engineer may deem necessary or pertinent, and with such samples of materials as may be required. The Contractor shall, at his expense, supply inspectors with such labor and assistance as may be necessary in the handling of materials for proper inspection. Inspectors shall have authority to reject defective material and to suspend any work that is being improperly done, subject to the final decision of the Engineer. Inspectors shall have no authority to permit deviations from, or to relax any of the provisions of these specifications without the written permission or instruction of the Engineer; nor to delay the Contractor by failure to inspect materials and work with reasonable promptness.

The payment of any compensation, whatever may be its character or form, or the giving of any gratuity, or the granting of any valuable favor, by the Contractor to any inspector, directly or indirectly, is strictly prohibited, and any such act on the part of the Contractor will constitute a violation of these specifications.[1]

6. Injuries to Persons and Property.—The Contractor shall be held alone responsible for all injuries to persons, and for all damages to the property of the city or others, caused by or resulting from the negligence of himself, his employees or agents, during the progress of, or connected with the prosecution of the work, whether within the limits of the work, or elsewhere. He must restore all injured property, including side-walks, curbing, sodding, pipes, conduits, sewers and other public or private property to a condition as good as it was when he entered upon the work.

7. Sanitary Conveniences; Nuisances.—The Contractor shall

[1] It may be objected that this requirement is unusual and unnecessary, since such practices are recognized as wrong, and as presumptive of fraud and malpractice on the part both of the contractor and the inspector. It cannot, however, be denied that in many cities such means are employed by contractors to unduly influence the action of inspectors and that not infrequently the latter not only accept, but persistently demand, valuable considerations from the contractor. Silence of the specifications on this point cannot, of course, be construed into consent, but there is no good reason for the silence. There should be left no excuse for misconception of the position of the city or of the engineer upon this point.

provide all necessary privy accommodations for the use of his employees on the street, and shall maintain the same in a clean and sanitary condition. He shall not create nor permit any nuisance to the public or to residents in the vicinity of the work.

8. Public Convenience.—No material, or other obstruction shall be placed within five feet of fire hydrants, which must be at all times readily accessible to the Fire Department.

During the progress of the work the convenience of the public and of the residents along the street must be provided for as far as practicable. Convenient access to driveways, houses and buildings along the street must be maintained wherever possible. Temporary approaches to and crossings of intersecting streets and sidewalks must be provided and kept in good condition, wherever practicable.

9. Barriers, Lights, Watchmen.—The Contractor shall provide and maintain such fences, barriers, "street closed" signs, red lights, and watchmen as may be necessary to prevent avoidable accidents to residents and to the public.

10. Disorderly Employees.—Disorderly, intemperate, or incompetent persons must not be employed, retained, or allowed upon the work. Foremen or workmen who neglect or refuse to comply with the instructions of the Engineer, shall, at his request, be promptly discharged, and shall not thereafter be re-employed without his consent.

11. Order and Progress of Doing Work.—The work under this contract shall be prosecuted at as many different points, at such times, and in such sections along the line of the work, and with such forces as the Engineer may form time to time deem necessary, and direct, to secure its completion within the contract time. Not more than one thousand (1,000) linear feet of the street shall be torn up, obstructed or closed to travel at any one time without the written permission of the Engineer. Completed portions of the pavement shall be opened to travel as directed by the Engineer, but such opening shall not be construed as an acceptance by the City of the work done. Where thus opened to public travel by the direction of the Engineer, the Contractor will not be held responsible for injuries to the work caused by such travel or public use, pending the final completion and acceptance of the whole work.

12. Grade and Contour of Pavement.—Roadway pavements shall be laid to such grades, crown and contour of surface as the plans may show or the Engineer may direct, and the surface of the com-

pleted pavement shall conform accurately to such grades, crown and contour. The designed surface of the completed pavement shall be considered as the datum or plane of reference in fixing the location or level of the sub-grade, of the pavement foundation, and of structures connected therewith. It will be hereafter referred to in these specifications as "The pavement datum."

13. City Monuments or Stakes.—The Contractor must carefully protect from disturbance or injury all city monuments, stakes and benchmarks, and shall not excavate nearer than five feet to any of them without the permission of the Engineer; or until they have been removed, witnessed, or otherwise disposed of by the Engineer.

14. Old Material.—All material or structures removed from the street and not required for the new construction, but which the city may desire to reserve, shall be delivered and neatly piled up in a corporation yard or elsewhere, by the Contractor, as the Engineer may direct. Such reserved material shall be considered in the custody of the Contractor until delivered at the place designated, and he will be held responsible for its care and protection, and must make good any losses occasioned by damage, theft, or misappropriation whlie it is on the street or en route to the place of storage. If the Contractor shall be required to haul such reserved material more than one-half mile, he shall be paid a reasonable price, to be agreed upon in advance, for the haul exceeding that distance.

Material taken from the work which is to be used in the new construction shall be compactly piled where it will least obstruct the sidewalks or adjoining sections of the street, and properly protected by the Contractor until it is required for use.

All old material removed from the work, including the material excavated in preparing the sub-grade, not reserved by the City nor to be used again in the work, shall belong to the Contractor and must be removed by him from the street as promptly as possible. It must not be placed on the sidewalks or adjacent streets, nor on any other street or property belonging to the City, nor on the property of private owners, without the written consent of the Engineer, or the owner of the property.

15. Storage of New Material.—The material for construction when brought upon the street shall be neatly piled so as to cause as little obstruction to travel as possible, and so that it may be conveniently inspected.

16. Rebuilding and Adjusting Street Structures.—Catch basins, manhole, sewer and water frames and covers, sewer inlets, water

pipes and other conduits, belonging to the City and within the limits of the work, shall, if necessary, be reset to the new lines and grades of the street and for this purpose good brick masonry of the original thickness, laid in Portland cement mortar shall be used. Great care must be taken to set all such structures as project through the pavement exactly to the grade and contour of the new street surface, and any defects in the conformity of such structures to the pavement datum, discovered at the time, or during the progress of the work, or during the guaranty period, stipulated in Sec. 25 shall be promptly remedied by the Contractor.

17. Clean Sidewalks.—During the progress of the work, the sidewalks and portions of the street adjoining the work, or in its vicinity, must not be obstructed or littered more than may be absolutely necessary, and the adjacent sidewalks must be kept clean.

18. Connection With Existing Pavements or Streets.—Wherever a new pavement joins or abuts against an existing pavement of a different kind, or an unpaved street, either at the end of the new pavement or at cross or intersecting streets, a line of stone headers shall be provided and set. The stone shall be of sound, hard limestone, sandstone, granite or bluestone, free from injurious imperfections. The separate stones shall be not less than three (3) feet long, at least eighteen (18) inches deep, not less than four and one-half (4 1/2) inches wide at the top, nor less than three (3) inches wide at the bottom. The top shall be of uniform width for each line of headers, and shall be dressed square and even. The ends shall be dressed to secure a joint not wider than one-half (1/2) inch for a depth of six inches from the top, and the sides dressed so as to secure good contact and close jointing with the pavement. The stones shall be set accurately with their tops at the pavement datum, on a bed of concrete nine (9) inches wide and six (6) inches deep, and after being set the trench shall be filled and rammed full of gravel or crushed stone.

All existing pavements adjoining or abutting against the new pavement, with their crosswalks, curbs, and gutters, shall be adjusted, or taken up and relaid, to conform to and connect with the pavement datum, to such an extent as the Engineer may direct.

Where the new and adjoining pavement are of the same kind, and headers are not used, the new and the old pavement must be properly joined and connected, as the Engineer may direct.

Stone headers will be paid for by the linear foot at the contract price for that item, and the other work embraced in this section

will be paid for at the contract prices for the several items, where such contract prices are provided; otherwise the work shall be considered as incidental work and shall be done at the expense of the Contractor.

19. Curbing to be Completed in Advance.—The setting of all new curbing and guttering and the redressing, resetting or readjustment of all old curbing must be completed at least 100 feet in advance of the construction of the street foundation.

20. Final Cleaning Up.—Immediately after the completion of the work or any consecutive portion of it, the Contractor shall remove from it all unused material, refuse and dirt placed by him on, or in the vicinity of the work, or resulting from its prosecution, and restore the street to a condition as clean as before the work was begun; and the new pavement shall be properly cleaned.

21. Measurements and Computations.—Unless otherwise distinctly provided in the contract and specifications, measurements computations and payments will be based upon the actual quantities of completed work, customary or conventional mehtods of measurement and computation to the contrary notwithstanding.

The area of street pavement shall be reckoned in square yards of completed pavement surface, deducting manholes, inlets and other openings in the surface of the pavement having an area of over three (3) square feet. Unless separately paid for under the contract stone headers and crosswalks will be measured as a part of the pavement surface.

22. The price for the pavement per square yard shall, unless otherwise stated herein, include the preparation of the sub-foundation, the construction of the foundation, the cushion course, and the pavement complete, including all the materials and labor required therefor.

23. Incidental Work at Contractor's Expense.—All the work to be done by the Contractor for which specific unit prices are not named in the contract, specified and enumerated in Sections 4, 5, 6, 7, 8, 9, 12, 13, 14, 15, 16, 17, 18, 19, and 20, as well as any minor details of work not specifically mentioned in the specifications, but obviously necessary for the proper completion of the work, shall be considered as incidental, and as being a part of and included with the work for which prices are named in the contract. The Contractor will not be entitled to any extra or additional compensation therefor.

24. Extra Work.—The City may require the Contractor to furnish such additional materials and to do such additional work,

not provided for in the contract and these specifications, but which may be found necessary or pertinent to the proper prosecution and completion of the work embraced in the contract, at prices to be agreed upon in writing, in advance. But no work other than that included in the contract and these specifications and which is covered by and to be paid for at the prices named in the contract, shall be done by the Contractor except upon a written order from the Engineer, which order shall describe the work to be done and name the compensation agreed upon therefor. In the absence of such written order from the Engineer the Contractor will not be entiteld to payment for any such additional or extra work.

In the same manner the city may omit or dispense with items or parts of the work, by previous agreement with the contractor, and a like written order by the engineer. But such additions, omissions or alterations shall not together increase or decrease the aggregate cost of the whole work more than fifteen per cent. (15%). Any changes in the plans, specifications, character of material used or method of doing the work that may increase or decrease the aggregate cost of the work more than fifteen per cent. (15%) may be authorized and validated only by a formal, supplemental contract, regularly executed by all the parties to the original contract.[1]

25. Guaranty.[2]—The Contractor shall guarantee that all the materials used and all the work done under this contract shall fully comply with the requirements of these specifications, the plans herein before referred to and the instructions of the Engineer. Any defects in the completed work, or any part of it, or any failure of the work to fully perform or endure the service for which it was intended,

[1] This section is intended as much for the control and limitation of city officials as of contractors. The practice of carelessly or purposely allowing municipal contracts to be expanded greatly beyond the stated limits or the original intended volume and cost without formal authorization by the proper municipal body in which the power to make contracts is lodged, is dangerous and wrong and should be prohibited. In one instance coming to the notice of the author a contract originally intended to cover $50,000 worth of work was expanded by the department head without any authority from the city council until the final estimate reached the enormous sum of over $400,000.

[2] As outlined in the introduction, these specifications are designed to secure the construction of the pavement in a proper manner, the city assuming responsibility for the character and utility of the work. The guarantee here proposed is therefore intended to cover only a proper compliance with the specifications, for which the contractor may properly be held responsible, and not the sufficiency or utility of the work, if constructed according to the specifications. The period of guaranty should therefore be short, not exceeding two years.

which, in the opinion of the Engineer, are attributable to the use of materials, skill, or workmanship not in compliance with the said specifications, plans and instructions, within a period of..... ..... .years after the date of the certificate of completion and acceptance, shall be regarded as prima facie and conclusive evidence that the Contractor has failed to comply with the said specifications, plans and instructions. And the Contractor shall, at his own expense, at such time and in such manner as the Engineer may direct, repair or take up and reconstruct any such defective work, in full compliance with the original specifications, plans and instructions. And as surety for the performance of this guaranty the Contractor's bond, required by the contract, shall remain in full force until the expiration of the period of .....years above stipulated in this section.

PREPARING THE SUB-GRADE

26. Grading.—The whole area to be occupied by the pavement and its foundation shall be excavated or filled up to a sub-grade at such an alevation that after being compacted by the roller, the surface will be.....inches below the pavement datum, and truly parallel thereto. In excavating, the earth must not be disturebd below the sub-grade. Plowing will not be permitted where the depth of earth to be removed is less than five (5) inches, and in no case must the plow be allowed to penetrate to within less than one inch of the sub-grade. Places that are found to be loose, or soft, or composed of unsuitable material, below sub-grade, must be dug out and refilled with sand, or other material as good as the average of that found on the street.

Where the natural surface of the ground shall be below the sub-grade, or shall become so by the removal of old pavement or other structures, it must be filled to the sub-grade in layers not exceeding five inches in depth, and each layer shall be thoroughly rolled or rammed before the next layer is placed upon it, and when the filling is completed the filled area must be properly trimmed and compacted by rolling or ramming to the true sub-grade, as in excavation. The material excavated from the street may be used for such filling, provided it be of suitable quality. Where it cannot be thus procured from the street it must be obtained by the Contractor elsewhere, in which case the actual quantity so obtained, measured after it is compacted in the street, will be paid for at the contract price for "earth

filling." The price bid for "earth excavation" will be paid for all material excavated above the sub-grade, measured in place on the street, which price includes the cost of disposing of the excavated material, whether as waste or filling, and of trimming and rolling or ramming the sub-grade, and of making it ready for the pavement foundation.

After the excavation is completed and the surface neatly trimmed, the whole area shall be well compacted by rolling with a roller weighing not less than five tons. Areas inaccessible to the roller shall be rammed until they are as well compacted as the rolled surface. When the rolling is completed the surface must be nowhere more than three-fourths inch below, nor mare than three-eighths inch above the true sub-grade. If, after the rolling is completed and before the pavement foundation is laid, the surface shall become disturbed in any way, it must be replaced and properly compacted.

Where the soil composing the sub-foundation is found to be wet or "springy," a system of soft tile drains, discharging into the street drainage system, shall be constructed by the Contractor, as directed by the Engineer. The tile shall be laid in trenches about one foot wide and from one to two feet deep. After the tile is in place the trenches shall be filled with crushed stone or gravel, well compacted by tamping. The tile will be paid for per linear foot at the contract price for the same, which price shall include the cost of excavating and refilling the trenches with crushed stone.

PAVEMENT FOUNDATION

27. Pavement foundation shall consist of hydraulic concrete, or of old pavement stone relaid, or of broken stone or gravel, as may be herein specified, constructed upon the sub-grade.[1]

[1] In the great majority of cases the most satisfactory and, in the end, the most economical foundation for a pavement is hydraulic cement concrete. Old paving-block foundation, if constructed as specified in Sect. 36, will give results equally as satisfactory, but if a fair market exists for the blocks taken up from the street, it will usually be found more economical to sell them and construct a concrete foundation for the new pavement. Broken stone or gravel foundations may serve the purpose fairly well upon a street of light travel, but it should never be used on streets of considerable or heavy travel. Its lower first cost is the only thing in its favor, but this will, in nearly every case, be more than offset by the better service and greater durability of the pavement, even on streets of light travel, if laid upon an adequate hydraulic concrete foundation. Proper repairs to pavement surfaces cut into for pipe work, etc., are difficult to make and hardly ever satisfactory over broken stone foundation for the reason that

HYDRAULIC CONCRETE FOUNDATION

28. Concrete.—Concrete shall be composed of Portland cement, sand, broken stone and water.

29. Portland Cement.[1]—Portland cement shall be defined as the

the lack of cohesion in the material allows it to loosen or crumble away from under the edge of the pavement surface, and it is difficult to restore it to its original solidity and strength. The first cost saved by its use is usually not great; for whenever its use would be permissible at all, a comparatively thin and lean concrete would give better results, at a very slight increase in cost. To illusrtate: On a suburban street with light travel a concrete foundation four inches in thickness, the concrete made with Portland cement in the ratio of 1 cement, 4 sand, and 8 stone, would be stronger and in every way better than a foundation eight inches in depth of broken stone. At the usual prices of materials and labor, the former may cost about $0.46 per sq. yd., and the latter about $0.40 per sq. yd.; but for the latter there would be required 1/9 cu. yd. more sub-foundation excavation, worth about four cents, so that the equivalent cost would he $0.44 per sq. yd. The difference, two cents per sq. yd., is insignificant when compared with the greater value, better service, and greater durability of a pavement on the concrete foundation. It is sometimes held that the broken stone foundation provides necessary sub-drainage. But all the standard pavements are, or soon become, impermeable to water from the surface, and seepage from the sub-foundation can he better taken care of by the sub-drainage specified in Sect. 26, which should usually cost not more than five cents per square yard of the pavement; and if drainage be required, these sub-drains should be used even with the broken stone foundation.

The practice of laying pavement surfaces, particularly those of asphalt, upon a foundation of old stone blocks, carelessly reset, with the joints unfilled with mortar, is all wrong and should never be resorted to. The integrity and durability of an asphalt pavement depends largely ypon the strength and rigidity of its foundation; to lay an asphalt surface, however good, over such an old block foundation, is an inexcusable waste of money.

Old stone block and cobble-stone pavements, that have become solidified in place by long travel over them, make a good foundation for asphalt or other pavements, provided they can be utilized without taking up or disturbing the old pavement; but such cases occur so rarely that they have not been considered in these specifications.

A thoroughly consolidated old McAdam pavement, if not worn too thin, also makes a very satisfactory pavement foundation if it can be used undisturbed, or by simply trimming off the high points.

Low places in old pavements, that are otherwise satisfactory for a foundation, may be brought to the proper elevation with hydraulic concrete. "Binder" material is usually specified for this purpose in foundations for asphalt pavements, but hydraulic concrete is both better and cheaper.

[1] The specifications for Portland cement here given are practically those adopted by the "American Society for Testing Materials,"

Natural Cement. While these specifications uniformly refer to the use of Portland cement, it is not intended to convey the idea that natural cement concrete

pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than three per cent. has been made subsequent to calcination.

Specific Gravity.—The specific gravity of the dry cement at a temperature of two hundred and twelve (212) degrees F. shall not be less than 3.10.

Fineness.—It shall be pulverized to such fineness that not more than eight (8) per cent. shall fail to pass a number one hundred (100) sieve and not more than twenty-five (25) per cent. shall fail to pass a number two hunbred (200) sieve.

Time of Setting.—At the temperature of sixty (60) degrees F. mortar made of neat cement shall not begin to set in less than thirty (30) minutes, nor set hard in less than one hour, but must set hard within ten (10) hours.

Strength.—When thoroughly mixed dry with clean, sharp, moderately coarse sand, in the ratio by weight of one part cement to three parts of sand, and then made into stiff mortar, briquets made from this mortar and exposed for one day to moist air and immersed in water for the balance of the periods named below,

is not suitable for pavement foundations; on the contrary, it may be used with entire confidence, as the experience in a large number of cities has proven beyond question. Whether Portland or natural cement shall be used is usually a question of relative cost. At the present very low prices of Portland cement in most cities, more strength in pavement foundations can usually be obtained per dollar expended for cement, from Portland than from natural cement. The specifications for natural cement, as adopted by the American Society for Testing Materials differ from those for Portland cement in the following particulars:

The **specific gravity** shall not be less than 2.8.

Fineness. The residue left on a No. 100 sieve shall not exceed 10 per cent., and on a No. 200 sieve shall not exceed 30 per cent.

Setting. It shall not begin to set in less than ten minutes, nor set hard in less than thirty minutes; but shall set hard within three hours.

Tensile Strength (per sq. in.).

Neat.	24 hours in moist air	50 to 100 lbs.
	7 days (1 day in air, 6 days in water)	100 to 200 lbs.
	28 days (1 day in air, 27 days in water)	200 to 300 lbs.
1 part cement, 3 parts sand.		
	7 days. (1 day in air, 6 days in water)	25 to 75 lbs.
	28 days. (1 day in air, 27 days in water)	75 to 150 lbs.

Soundness. Standard pats kept in air and in water should remain firm and hard and show no signs of cracking or disintegration.

shall develop a tensile strength per square inch not less than the following:

In seven days	175 pounds.
In twenty-eight days	250 pounds.

Constancy of Volume.—When subjected to standard tests for constancy of volume, the cement shall show no tendency to swell or crack.

Composition.—The cement shall not contain more than one and three-fourths (1.75) per cent. of anhydrous sulphuric acid, nor more than four (4) per cent. of magnesia.

Tests.—Cement tests shall be conducted in accordance with the methods recommended by the "Committee on Uniform Tests of Cement" of the American Society of Civil Engineers.

Conditions.—All cement shall be supplied in original packages with the brand of the manufacturer marked on each package. It shall be protected during transportation from rain and moisture. It shall be delivered upon the work at least ten (10) days (exclusive of Sundays and holidays) before it is to be used, in oredr to allow of proper inspection, and the contractor shall furnish all necessary facilities for such inspection. Brands of cement without established good reputation, or not heretofore used in the City of .....may be rejected; or they will be accepted only after they satisfactorily pass the 28-day test. Rejected cement must be at once removed from the street.

30. **Sand.**—Sand for concrete shall be composed of grains not softer than hard limestone. It shall be moderately coarse and preferably made up of grains of varying size producing a mass with low percentage of voids. It shall not contain, in all, more than seven (7) per cent. by volume of clay, loam, mica scales, silt, or other objectionable inorganic matter, nor more than one (1) per cent. of organic matter.

31. **Broken Stone.**—Broken stone for concrete shall be of hard and sound limestone or other stone equally hard and durable, broken to a roughly cubical form. It shall be screened through efficient revolving screens, and only such fragments as have passed through circular screen openings two and one-half (2 1/2) inches in diameter, shall be used. If the crushed dust and fine fragments be not screened out, the stone must be so handled that the fine material

will be evenly distributed through the mass when it reaches the concrete platform or mixer.[1]

32. Water.—Water used for concrete shall be fresh, and reasonably clean.

33. Care and Handling of Concrete Material.—Cement must not be allowed to become wet or damp. It shall be stored until used, whether in storehouses or on the street, so that no part of the packages shall be nearer than four (4) inches to the ground or pavement, and shall be effectually covered so that rain cannot reach it. Sand and stone, if stored on the street, shall be on lumber floors.[2] The stone shall be thoroughly wetted a sufficient time before being placed in the concrete to allow any surplus water to drain away, but shall remain moist where it reaches the concrete platform or mixer.

34. Ratio of Concrete Materials.—Concrete will be composed of one part Portland cement... .....parts of sand and .... .parts of broken stone, and the proper quantity of water, all measured by volume.[3] The unit of measurement shall

[1] The frequent requirement that the fine material shall be screened out, is not necessary or advisable. Experiments and experience have shown conclusively that unless an unusual amount of fine material and "dust" be present, or unless this fine material be allowed to separate and aggregate in masses by itself, the resulting concrete is improved rather than deteriorated by its presence.

Where there is an unusual excess of "dust" in the crushed stone, the quantity of sand used in the concrete should be decreased accordingly.

[2] Many specifications do not require this and in a number of cities where the specifications do require it, contractors habitually neglect to comply. When stone and sand are deposited directly upon the earth, it is very difficult to avoid taking up earth and mud with the materials, particularly when the street is wet and muddy. Lumps of soil and débris unquestionably injure the concrete. The cost of providing a lumber floor is comparatively small, as the plank may be used over and over again. Specifications should, therefore, contain this requirement and it should be enforced.

[3] The ratios of the materials may appropriately be varied with the strength and soundness of the sub-foundation, the amount of travel on the street, and with the thickness of foundation it is proposed to use. Where good materials are used and the work is properly done, a 1 : 3 : 5 concrete six inches thick is sufficient for streets of the heaviest travel. For streets of light travel a 1 : 5 : 9 concrete will usually give entirely satisfactory results. The most economical thickness for a concrete foundation is an important consideration. The strength of concrete may be said to increase, within usual limits of practice, with the ratio of cement in it. The strength of concrete beams or slabs increases in the ratio of the square of their depth. To secure a required amount of strength in a pavement foundation, we may therefore vary the richness of the concrete and the depth of the foundation so as to secure the requisite strength at the least total cost of

be the barrel of cement which shall be considered as containing four (4) cubic feet. The materials shall each be measured in such manner and with such accuracy that the quantities used will not vary more than seven (7) per cent. from the quantities required in the ratio named above for each batch of concrete

35. Mixing Concrete.—If mixed by hand, concrete shall be mixed on platforms of iron or wood of sufficient size to admit of proper manipulation of the concrete. The sand shall be first spread evenly over the platform and the cement evenly distributed over the sand. These two materials shall then be mixed dry until a uniform and homogeneous mixture is secured. Sufficient water shall then be added and the mixing resumed and continued until a mortar of uniform consistency and texture is produced and distributed in an even layer over the platform. The stone shall then be distributed over the mortar and mixed therewith until the mortar is evenly distributed through the mass and every fragment of stone is well coated with mortar, sufficient additional water being added as the mixing progresses to produce a rather wet, but not sloppy, concrete.[1] Machine mixing of concrete will be preferred, provided

materials and labor. This will be influenced by the cost of materials and labor in each particular locality.

Within certain workable limits there is no reason why the same principles of proportioning the strength of a pavement foundation to the work required of it should not be applied as are employed in designing other engineering structures.

The practice, usual in many cities, of adopting general specifications requiring a standard thickness of foundation and composition of concrete, and applying these to all streets, regardless of the quantity and character of travel which the pavement is expected to carry, is illogical and often very wasteful. If such a standard foundation is sufficient for the streets of heaviest travel, it is obviously a sheer waste of money to use it on the suburban streets carrying the lightest travel. It is therefore better in preparing standard specifications for pavement in any city to leave blanks for the ratios of the concrete and for the thickness of the foundation, to be filled in, in each individual case, as the judgment of the engineer may dictate.

While it is important that the foundation of any pavement shall be adequate, it is inexcusable to waste money in providing superfluous strength. For the great majority of suburban streets, carrying but little except the local travel, a foundation four inches thick made of good Portland cement concrete in the ratios of 1 : 4 : 8 will prove entirely satisfactory. Hundreds of such streets paved over a foundation of that thickness, made of natural cement concrete in the ratios of 1 : 2 : 4 can be cited where the foundation has proved entirely satisfactory.

The character and firmness of the sub-foundation must, of course, be taken into consideration in designing the foundation.

[1] The routine here described produces better concrete with less expenditure of labor, than the one often followed of putting all the dry materials on the concrete

the machine used secures equal accuracy in the ratios of materials and equally as good mixing as prescribed above for hand-mixing. Machine-mixed concrete must be delivered from the machine upon a wood or metal platform, or directly into barrows.

36. Placing the Concrete.—Concrete shall be placed on the subgrade in such a manner as to prevent as far as possible the separation of the mortar from the stone. It shall be evenly distributed in a single horizontal layer of such depth that, after ramming, it will be not less than..... .....inches thick. Immediately after being so placed it shall be well rammed until a compact mass is produced with its upper surface parallel to and.....inches below the pavement datum. Depressions that may appear during the ramming may be filled with concrete of the same composition as used for the foundation, except that smaller-sized stone shall be used; mortar alone must not be used for this purpose, nor shall the upper surface of the concrete be plastered with mortar. The surface of the concrete shall not be broomed or troweled.[1]

37. Setting of Concrete.—After the concrete is completed it shall remain undisturbed until it be firmly set. The time allowed for setting shall not be less than five days, and as much longer as, in the judgment of the Engineer, may be necessary, depending upon the temperature of the weather and the setting qualities of the cement. During this period no hauling or traveling over the concrete must be permitted unless its surface be first protected by a covering of plank. The Contractor shall, if necessary, keep the concrete moist by wetting it, with hose, or otherwise, until twenty-four (24) hours before it is to be covered with the pavement surface.

38. Measurement of Concrete.—Concrete will be measured and computed in cubic yards as found completed on the street, the thick-

board before any mixing is begun. The writer has proved this from actual records covering a large quantity of work.

[1] The objections to using mortar for plastering over the concrete are: that it is more costly than concrete; that the two materials may, under certain conditions, separate and the thin mortar surface break up under travel; that, if permitted, the mortar may be used to cover up defective concrete, and that in the case of asphalt pavements the pavement surface is more likely to "shift" on the smooth surface of the mortar than on the rough surface of the concrete. The practice of going over the fresh concrete with street brooms should not be permitted. The only argument in favor of it is that it may be used to conceal defective patches in the concrete.

ness being taken as .... inches. The contract price for concrete foundation covers the cost of providing all the materials required, making, placing and ramming the concrete, and keeping it moist for the necessary period.

FOUNDATION OF OLD PAVING STONE

39. Foundations made of old stone paving blocks shall be constructed as follows:

Upon the sub-grade prepared as specified in Section 26, shall be spread a layer of good sand to an even depth of one and one-half (1 1/2) inches. The paving blocks, whether taken up from the street to be paved, or brought from other streets or storage yards, shall be cleaned of all adhering earth, dirt and street refuse. The blocks shall then be set on the bed of sand, on edge, perpendicular to the grade, with their long dimension at right angles to the line of the street, in courses composed of stones of the same width, extending entirely across and at right angles to the axis of the street. Stones in adjoining courses shall break joint at least two inches. Joints between courses or stones, or along the curbstones, shall not exceed one inch in width. The stone shall be fitted closely around manholes or other structures in the street. The stones shall be so set in the bed of sand that after being rammed as hereafter specified, their tops shall be at the proper grade. After being thus set in place the stone shall be rammed with paving rammers having wooden faces and weighing not less than thirty (30) pounds, so as to force each stone to a good bearing in the sand below, and to bring its top to a uniform grade, parallel to and ..... inches below the pavement datum. No stone shall project more than one-fourth (1/4) inch above the proper grade, and stones whose tops, after ramming, are more than one-half (1/2) inch below such grade, shall be raised, additional sand placed under them, and reset and re-rammed to the proper grade and bearing. After the ramming shall have been completed, the joints between the stones shall be filled with mortar. The mortar shall be composed of Portland cement and sand, complying with the specifications for these materials in Sections 29 and 30. One part of cement and three parts of sand, by volume, shall be thoroughly mixed dry, and then made into mortar with sufficient quantity of water to produce a mortar of such consistency that it will just flow freely into the joints between the stones. All the joints between the stones must be

completely filled with this mortar before it has begun to set. The mortar filling shall be brought even with, but not above, the tops of the stones. After the filling is thus completed, the foundation must stand undisturbed until the mortar shall have set firmly, in no case less than five days. The mortar must be kept moist during the period allowed for setting.[1]

Old stone foundation will be measured in square yards, in place after completion. The contract price includes the cost of handling and cleaning the stone, supplying and placing the bed of sand, setting and ramming the stone, supplying the materials for, making and placing the mortar in the joints and watering the street while the mortar is setting. Where stone is procured from other streets, or from storage yards, the Contractor will be required to load, haul and unload them, and will be allowed for this service a price of ..... cents per cubic yard for loading and unloading, plus ..... cents per cubic yard for each one-half mile, or fraction thereof, over which they are hauled by the nearest practicable route, the measurement to be made after the stone is set in the street, without deduction for joints.

40. Broken-stone Foundation.—The sub-grade for broken-stone foundation shall be prepared as specified in Section 26, except that

[1] See foot-note, p. 23. The cost of filling the joints of old block pavement with mortar or grout is considerable. It will hardly ever be less than 20 cents and may exceed 35 cents per square yard, depending on the volume of joints and the local cost of material and labor. The cost of resetting and ramming the blocks with proper care will usually be from 10 cents to 12 cents per square yard, so that the cost of the foundation, exclusive of the value of the blocks, may vary from 30 cents to 47 cents per square yard.

As a good concrete foundation 6 inches in depth can be laid for from 70 to 90 cents per square yard, it is obvious that if the old blocks can be sold for as much as the difference between the cost of the old block and the concrete foundation, nothing will be saved by using the old block foundation. In at least one city, asphalt pavement has been extensively laid over old stone block foundation relaid in a very careless manner, the joints being filled usually with the old sand or loam found in the street. This practice cannot be too strongly condemned. Asphalt pavement surfaces resting on such a foundation are necessarily short-lived and unsatisfactory. The practice of opening the street to travel for a period after the blocks are relaid and before the asphalt surface is applied, helps, under favorable conditions, to consolidate the foundation, but does not remove the objections to it. If heavy rains intervene, the sub-foundation becomes saturated with water, and its resistance so reduced that the stone blocks settle out of shape, particularly in soft spots, and they are usually hastily raised and reset just before the asphalt surface is applied. The result is an insecure foundation fatal to the durability and usefulness of the pavement.

the rolling may be omitted at the option of the Contractor. The broken or crushed stone shall be of hard, durable stone. The foundation shall have an aggregate thickness of.....inches and shall be constructed in two courses, as follows:

The broken stone used in the first course shall be of such size that it will all pass through a screen having openings three (3) inches in diameter, and will all be retained on a screen having openings one (1) inch in diameter. This stone shall be evenly spread over the sub-grade to such a thickness that after being thoroughly consolidated by rolling, its upper surface shall be three-fourths inch below, and parallel to the surface of the foundation when completed. It shall then be rolled with a road-roller weighing not less than ten (10) tons until the stone is thoroughly compacted.

The second course, composed of screenings, all of which shall have passed through a screen with openings one inch in diameter, shall then be spread over the first course and well raked into the voids of the first course. It shall then be thoroughly wetted, and shall be rolled with the ten-ton roller until the fine stone is driven into the interstices of the first course and the whole thoroughly consolidated, the wetting being repeated while the rolling continues. Additional screenings shall be added and rolled in where necessary to bring the surface to the proper elevation. When completed, the top surface of the foundation shall be..... ..inches below, and parallel to the pavement datum. No part of the upper surface of the completed foundation shall project more than one-fourth (1/4) inch above, nor shall it be more than one-half (1/2) inch below the grade and contour above specified.

Gravel of a quality satisfactory to the Engineer may with his written consent be substituted for broken stone. If of assorted sizes, such as will compress into a mass having not more than thirty (30) per cent. of voids, the foundation may be constructed in a single layer, graded, watered and rolled, as prescribed above for broken stone.[1]

41. Measurement.—Broken-stone and gravel foundation will be measured and computed by the cubic yard in the street as completed, without any allowance for consolidation by the roller or for settlement into the sub-grade, the thickness being taken as.....

[1] Where there is a possibility that gravel may be used, the contractor should be asked to name prices for the gravel foundation as well as the stone foundation, since, unless this be done, the change from the one material to the other might be held to be illegal.

.....inches. The contract price for it shall cover the cost of supplying the material, placing it on the street, and grading, watering and rolling it.

SHEET ASPHALT PAVEMENT

Note.—A number of distinct varieties of asphalt are now used for asphalt pavements, either alone or mixed. These different varieties differ from each other quite widely in their physical and chemical properties. Thus, in the form called "refined asphalt" some of their properties are shown by the following table, the data for which is taken from the second edition of Richardson's "The Modern Asphalt Pavement."

COMPARATIVE PROPERTIES OF DIFFERENT REFINED ASPHALTS

	Trinidad, average	Bermudez, average of two samples	Maracaibo, average of six samples	Calif. "D" grade, average of two samples	Gilsonite, average of two samples
Softens, degrees F..	180	165	225	132	280
Flows, degrees F...	190	175	236	151	300
Penetration at 78° F.	7	24	21	48	0
Loss, heated to 325° for 7 hours, %.	1.1	3.7	3.2	1.7	1.6
Loss, heated to 400° for 7 hours, %.	4.0	8.8	5.5	7.1	2.6
Bitumen soluble in CS_2.	56.5	95.5	93.9	99.3	99.4
Inorganic, other than bitumen.	36.5	2.2	2.9	0.3	0.5
Bitumen soluble in naphtha.	35.6	65.6	51.1	69.6	47.2
Bitumen sol. in carbon tetrachloride.	98.7	99.0	93.2	95.7	99.8
Fixed carbon.....	10.8	13.7	17.2	17.6	13.2

The practice has been heretofore, and is at the present time, to attempt to make specifications for asphalt pavements broad enough to include all

the various varieties of asphalts, under general requirements which shall admit these, and any new varieties that may appear on the market suitable for the purpose, the object being to permit a wide range of competition. This makes it exceedingly difficult if not impossible to frame specifications that shall be sufficiently explicit and at the same time sufficiently broad to admit these several differing materials. This practice has been adhered to in these specifications, though in this respect they are far from satisfactory to the author. So long as it continues to be the policy of cities to admit these various varieties of bitumen under the same general requirements for crude and refined material, such objectionable specifications cannot be avoided. Even with the great latitude now provided they exclude some materials with which good pavements have been made.

Two remedies for this unsatisfactory condition seem practicable.

1. A city might purchase a sufficient supply of refined asphalt for its use after asking for proposals under suitable specifications with alternative requirements for the different varieties on the market, and after bids are received and the samples accompanying them have been properly examined in the laboratory, award contracts for a supply of one or more kinds, as might seem best for the interests of the city. Stocks of these would be delivered, tested and stored accordingly, in good time for the season's work. Specifications for construction with special reference to the kind of asphalt it is proposed to use could then be prepared, the contractors to be supplied with asphalt at the city storage yard at a stipulated price per ton. This plan would possess a number of advantages. A similar plan is quite commonly in use with reference to hydraulic cement.

2. Specifications might be framed with special reference to the properties and qualities to be possessed by the *asphaltic cement*, permitting a liberal range as to the crude and refined bitumens to be used in manufacturing this cement. This would be considered, at the present time, a radical departure from well established custom, but the author sees no reason why it should not be satisfactorily employed.

A sheet asphalt pavement is composed of two essential elements; a mineral aggregate made up of sand of assorted sizes and mineral "dust" and a bituminous cement. When properly compounded, manipulated and compressed these elements make up a bituminous concrete suitable for use as a wearing surface for streets and roads.

The character of the sand is important and we have now sufficient knowledge from experience to specify a sand that will give, approximately, the best results.

The bituminous cement is, however, the element of most importance, and upon its suitability for the purpose depends very largely the utility and durability of the pavements made with it.

It is important that this asphaltic cement shall possess certain properties and qualities, most of which we are now able to define satisfactorily, but

others require further practical and experimental study, and some tests not now in use would doubtless be desirable.

It is not a matter of importance what particular crude or refined materials enter into the composition of this cement if the resulting product is satisfactory in use. The prime requisite is a paving cement that shall possess in a high degree the chemical and physical qualities required for making an asphalt pavement of the best quality. If we can devise standards and tests that will enable us to secure such a cement we need not be concerned about its antecedents.

It would be well worth while for paving engineers and those who have laboratory facilities to give attention to this matter. If it shall be found practicable to define satisfactorily the qualities the cement should possess without reference to the materials from which it is compounded, a great advance will have been made, and our asphalt paving specifications could not only be greatly simplified, but much greater precision and definiteness secured.

While great advances have been made in the art of building sheet asphalt pavements and in the framing of specifications for its construction, too many of the specifications still in use are antiquated, indefinite and unsatisfactory. Some of these contain requirements that, if literally enforced, would prevent the attainment of the best results. They are largely survivals of the time when little was known either practically or technically of the science and art of constructing the pavements, outside of the promoters and contractors in the business, who consequently dictated, in a large measure, the specifications used. City engineers were compelled to rely largely on the presumption that the guarantee clauses of the contracts would insure good results, and allowed the contractor wide latitude in the conduct of the work.

While there is undoubtedly much yet to learn, even by the experts, in the matter of the materials to be used, a quite satisfactory working basis has been arrived at, particularly as to the practical side of the work, and a large mass of data accumulated by study and experience is available to the municipal engineer, and the services of independent experts is readily obtainable. There is no longer any good reason, therefore, why the character of the materials to be used, the methods followed, and the quality of the work secured should not be quite definitely and fully specified in the same manner and to the same extent as in the case of other kinds of pavement and with equally satisfactory results.

SPECIFICATIONS

42. General.—Asphalt pavement surface shall be laid upon a foundation of hydraulic cement concrete, or of stone blocks relaid, over a sub-grade, to be constructed in accordance with Articles 26, 28, 29, 30, 31, 32, 33, 34, 35, 36 and 37.

Asphalt pavement surface shall be constructed in two courses, called the base-course and the surface-course. The base-course may be from one (1) inch to one and one-half (1 1/2) inches thick, and the surface-course may be from one (1) inch to two (2) inches thick, as shall be hereafter specified.

43. Crude Asphalt.—The cementing element in asphalt pavements shall be prepared from crude native, solid asphalts or from the proper distillation of crude asphaltic oils.

Crude asphalts as obtained from the mines or natural deposits shall be properly refined to drive off water and to separate foreign substances, by melting at a temperature not exceeding four hundred and fifty degrees F. (450° F.). Crude asphalts of the quality commonly called "glance pitch" or "iron pitch" which do not distinctly soften at a temperature of two hundred degrees F. (200° F.), and detached or deteriorated material from deposits otherwise acceptable will be rejected.

44. Refined Asphalt.—Refined asphalt produced from native crude asphalt shall be free from water and shall not contain an injurious quantity of light oils or foreign matter. It shall not contain more than four per cent. (4%) of organic matter nor more than thirty-six per cent. (36%) of inorganic matter other than bitumen, and not more than eighteen per cent. (18%) of fixed carbon, and not less than fifty-five per cent. (55%) of bitumen soluble in cold carbon disulphide. Of the bitumen soluble in carbon di-sulphide not less than sixty-three per cent. (63%) shall be soluble in Pennsylvania petroleum naphtha of specific gravity eighty-eight (88) degrees Baume at a temperature of sixty-five degrees Fahrenheit (65° F.) and not less than ninety-eight per cent. (98%) shall be soluble in chemically pure carbon tetra-chloride. When exposed for seven hours to a temperature of three hundred and twenty-five degrees F. (325° F.) in a shallow dish the bottom of which is covered with bitumen to a depth of three-fourths (3/4) inch, the refined asphalt shall not lose more than five per cent. (5%) by evaporation.

Asphalts that are injuriously affected, in the pavement, by water (to be determined by the test immediately hereinafter described), shall not be used except under the conditions specified in Section 45. Cylinders made from the surface mixture it is proposed to use, one (1) inch in diameter and two (2) inches long, compressed to a density of two and one-tenth (2.1), when immersed forty-five (45) days in ten (10) times their volume of rain-water, shall retain a sound surface, unchanged and uncorroded by the action of the water.

Refined asphalts resulting from the distillation of crude asphaltic oils will not be accepted unless the distillation shall have been effected by the use of suitable apparatus, at a temperature not exceeding seven hundred (700) degrees F. The bitumen must not be over-distilled and "cut back" by adding oil. The product, to be acceptable, shall possess the following qualities: It shall melt and flow at a temperature not below one hundred and forty (140) degrees F., but below a temperature of one hundred and eighty (180) degrees F., and when tested in the standard New York State closed oil-testing apparatus shall not flash at a temperature below four hundred and fifty (450) degrees F. When exposed in a shallow dish, the bottom of which is covered to a depth of three-fourths (3/4) inch with the bitumen, to a temperature of four hundred (400) degrees F., for seven (7) hours, it shall not lose by evaporation more than seven (7) per cent. by weight. Not less than ninety-eight (98) per cent. shall be soluble in cold carbon di-sulphide, and not less than sixty-five (65) per cent., nor more than seventy-five (75) per cent. of the bitumen shall be soluble in cold Pennsylvania naphtha of gravity eighty-eight (88) degrees Baume. Not less than ninety-nine (99) per cent. of the bitumen shall be soluble in carbon tetra-chloride, and it shall not contain more than sixteen (16) per cent. of fixed carbon.[1]

Bitumens resulting from destructive distillation or from artificial oxidation, and bituminous compounds prepared from oil or oil residuums heated with sulphur or other substances, or coal or gas

[1] There has been much discussion as to the suitableness of these oil asphalts, called "residual pitches," for use in making asphalt pavements. When properly prepared from suitable asphaltic oils, so as to comply with the specifications here given, there can be no doubt that good pavements can be made with them. But as they appear on the market, being usually produced at different localities and refineries from crude oils of differing qualities, distilled by somewhat differing methods, and usually at temperatures of from 900 degrees to 1200 degrees, they are likely to vary so greatly in quality as to make their use inadvisable without careful technical inspection. Unless, therefore, the engineer is prepared to make, or to have such inspection made, it is hardly wise or safe to permit their use. They stand, in this respect, upon a footing different from the better-known natural asphalts obtained from large deposits of practically uniform character and quality, where the simpler process of refining is less likely to effect injuriously the chemical quality of the material.

It may be confidently predicted that any of these "residual pitches" which comply with these specifications will, if properly handled, make a good pavement.

tars, will not be accepted, nor shall they be mixed with the asphalt used.[1]

45. Asphalts that are injuriously affected by water, and those whose practical value for making pavements has not been established, in the judgment of the City, by sufficient experience, will not be accepted except under such special bond and guaranty provisions as the City may prescribe.[2]

46. Full information as to the source and character of the crude asphalt and the method of refining it shall be furnished to the Engineer and verified by such evidence as he may require.

47. Softening or Tempering Agent.—For softening and tempering refined asphalt, petroleum residuum oil or liquid asphalt shall be used. It shall be free from water, coke, and other impurities. Its specific gravity shall not be below 0.92, nor above 1.04. Its flash test (determined in the standard New York State closed oil-testing apparatus) shall not be under three hundred and fifty (350) degrees F., and when exposed for seven (7) hours to a temperature of three hundred and twenty-five (325) degrees F., in a shallow open dish, the bottom of which is covered by the oil to a depth of three-fourths (3/4) inch, it shall not lose more than five (5) per cent. by evaporation. It shall not contain more than ten (10) per cent. of paraffine scale.

48. Sand.—A superior quality of sand will be required and this must be secured, if necessary, by the admixture of two or more sands. The sand shall be silicious and so free from organic matter, mica, soft grains, and other impurities, that these shall not aggregate more than two (2) per cent. of the mass. The grains shall, preferably, be moderately "sharp" or angular, and must be of assorted sizes so that the voids in the compacted mass of dry sand shall not

[1] The possibility that some of these compounds or artificial asphalts, may be suitable for use in pavements is not denied. But in the absence of a fuller knowledge of them than we now have, and in the light of present experience, the only safe course is to reject them.

[2] It is not intended here to enter into an extended discussion of the fact that some asphalts are injuriously affected by water, and the bearing which this fact should have upon the selection of an asphalt for pavement purposes. There can be no doubt that modern treatment and methods of construction have tended to diminish but not wholly to prevent the disintegrating effect of water upon pavements made with such asphalt, and if the engineer could be certain that his pavements would be constructed by contractors guided by long experience and the best expert advice, he might perhaps safely disregard this provision. Since in practice he can have no such assurance, the provision is a wise one and it does not involve any serious or material hardship to the contractor.

exceed thirty three (33) per cent. A typical sand, to be approximated as closely as practicable, will give the following sieve tests, the sieves being used in the order named:

3 per cent. of the whole will pass No. 200 sieve.
15 per cent. of the whole will pass No. 100 sieve.
18 per cent. of the whole will pass No. 80 sieve.
30 per cent. of the whole will pass No. 50 sieve.
24 per cent. of the whole will pass No. 30 sieve.
10 per cent. of the whole will pass No. 10 sieve.

and none will fail to pass the No. 10 sieve.[1]

49. Pulverized Stone.—This may consist of limestone or other sound stone or sand, pulverized to such fineness that the whole will pass the No. 50 sieve, not more than ten (10) per cent. will be retained on the No. 100 sieve, and at least seventy (70) per cent. of it will pass the No. 200 sieve. Portland cement may be partly substituted for pulverized stone, where the Engineer shall so direct.[2] Portland cement thus used will be paid for at the price bid per barrel for the same, in addition to the price paid per square yard for the pavement surface. The pulverized material must be thoroughly dry when used.

50. Asphaltic Paving Cement.—Asphalt Paving Cement shall be prepared from the refined asphalt described in Sect. 44 and the tempering agent described in Sect. 47. The refined asphalt, together with the asphalt in the tempering agent, shall constitute not less than sixty per cent. (60%) of the asphaltic cement.

The refined asphalt and the tempering agent shall be mixed and

[1] It is now well recognized that the character and quality of the sand used is one of the most important elements in determining the utility and durability of an asphalt pavement. A satisfactory sand should be insisted on, even if it involves a very considerable increase in the first cost of the work.

While our knowledge of the subject is not complete, experience seems to indicate pretty clearly that a sand of the quality and size-grading here specified as typical, may be depended upon to produce a good pavement.

[2] The use of Portland cement in surface mixtures to be laid on streets of heavy travel, or those exposed to damp foundations, is very strongly recommended. On streets of the heaviest travel, or where the pavement will be exposed to unfavorable conditions of dampness, particularly if the pulverized stone is not very finely ground, the Portland cement may constitute twenty per cent. of the pulverized material, or "dust," as it is commonly called. Ordinarily from five to ten per cent. may be used to advantage on all streets of moderately heavy travel.

melted together at a temperature not below two hundred and seventy-five degrees F. (275° F.), and not above three hundred and twenty-five degrees Fahrenheit (325° F.), and thoroughly incorporated by agitation until a homogeneous cement is produced. The agitation shall be continued until the cement is used.

The asphaltic cement at a temperature of seventy-seven degrees F. (77° F.) shall be of such consistency as to show a penetration of from forty to eighty hundredths of a centimeter, as the engineer may direct for each street, when tested with the standard Dow penetration apparatus, using a number two cambric needle loaded with one hundred grams. When a cement of a consistency satisfactory to the engineer has been produced and approved for any street a sample of it shall be kept as a standard and all subsequent batches or kettles must be made to conform thereto, suitable apparatus and tests being employed to determine the correspondence of each new batch with the standard.[1] The asphaltic cement when at its melting temperature shall be so viscous that it will draw out into moderately long fine threads which shall be free from lumps or raggedness and shall possess satisfactory adhesive and cementitious qualities.[2]

51. Composition and Preparation of Asphalt Surface Mixture.—The surface course shall be composed of the materials specified in Sections 43, 44, 45, 46, 47, 48, 49, and 50 mixed in such ratios by weight as the Engineer may direct or approve. A typical mixture will contain:

[1] For determining the consistency of individual batches of asphalt paving cement with a standard sample, the flow-plate method is most convenient and sufficiently accurate. For a description of the latest improved form of this apparatus see Engineering News of Aug. 22, 1912, p. 347. It can only be used, however, where the cements to be compared are of the same general composition—the same refined asphalt and tempering agent—as the standard.

[2] The practical value of the exact determination of the ductility of asphalt paving cements is regarded by the author as not well established. It is customary, however, in most recent specifications to require it. Some asphaltic cements that have been quite successfully used for pavements have not compiled with such requirements, while good coal-tar pitches will greatly exceed them. Where this test is used the usual specification requires that a briquette of asphaltic cement having a cross-section of one square centimeter, at penetration 50, shall elongate to the extent of not less than 20 nor more than 85 centimeters at 77° F. If the asphaltic cement varies from 50 penetration an increase or decrease of at least 2 centimeters will be required for each five points above or below 50 penetration (Dow apparatus to be used).

Sand	100.0 lbs.
Pulverized mineral matter passing No. 200 screen, including that found in the paving cement	17.5 lbs.
Pure bitumen (in paving cement)	13.5 lbs.

But the quantities of pulverized stone and of asphaltic cement shall be varied as may be found necessary or desirable by the Engineer to suit the purity of the asphaltic cement, the character of the sand, the climatic conditions, and the varying quantity and character of travel on the street to be paved; and Portland cement may be substituted partly or wholly for the pulverized stone, when directed by the Engineer. The surface-course mixture shall be submitted to the Engineer and approved by him before any is laid upon the street.

The mixing shall be accomplished in a mechanical mixing apparatus capable of rapidly and effectually incorporating the materials together, and each batch must remain in the mixer a sufficient length of time to effect a perfect mixture. The sand shall be separately heated and shall reach the mixing apparatus at a temperature not above three hundred and fifty (350) degrees F., nor below three hundred and twenty (320) degrees F. The pulverized stone shall be at such a temperature that when mixed with the sand the temperature of the mixed mass shall not be above three hundred and fifty (350) degrees F., nor below three hundred and twenty (320) degrees F. The sand shall be first placed in the mixer, followed by the pulverized stone, and these two materials shall be thoroughly mixed together before the asphaltic cement is added. The asphaltic cement at a temperature not above three hundred and fifty (350) degrees, nor below three hundred (300) degrees F. shall then be added in such a way as to evenly distribute it over the sand and pulverized stone, and the mixing continued until the materials are thoroughly incorporated into a perfectly uniform and homogeneous mass, with the grains of sand completely covered with cement. Suitable thermometers shall be constantly used to determine the temperatures specified herein. Great care must be taken to accurately weigh and proportion the materials charged into the mixer.[1]

[1] It should be noted, in a general way, that there is quite a difference in the temperature to which different asphalts may be safely subjected.

Trinidad asphalt, and the California residual pitches, will not be injured by

52. Stone for Base-course.—Stone screenings for base-course shall be of crushed, hard, durable stone. The portion used shall all be retained upon a No. 8 sieve, or screen, and shall all pass a screen having square meshes, the linear dimensions of the openings in which are one-half (1/2) inch less than the thickness of the base-course.

53. Composition of Base-course.—The base-course shall be composed of the crushed stone specified in Section 52, mixed with the asphaltic cement, sand and pulverized stone specified in Sections 50, 48 and 49, but the asphaltic cement shall be of such hardness as the engineer may direct.

A typical base-course mixture will be composed as follows:

Crushed stone	100	lbs.
Sand	42	lbs.
Pure bitumen (in asphaltic cement)	7	lbs.
Pulverized stone	7 1/2	lbs.

But the mixture shall be such that when placed on the street and compressed by the roller the mass shall be dense and the voids in the stone completely filled; and to accomplish this the quantity of crushed stone used in the mixture may be increased or decreased, as the volume of its voids may require, in order that they may be completely filled.[1]

54. Mixing the Base-course.—The materials for the base-course shall be heated and mixed in the same general manner as prescribed for the surface-course (Sect. 51), the crushed stone being delivered first in the mixer. The temperature of the mixture as it comes from the mixer being not above three hundred and twenty-five (325) degrees F., nor below three hundred (300) degrees F.

55. Laying Asphalt Pavement, General.—Asphalt pavement must not be laid except when the surface upon which it is to be placed

the higher range of temperatures named in these specifications, while Bermudez and some other asphalts should be worked at as nearly as possible to the lower range of temperatures named. The relative amount of loss of the different asphalts when exposed for seven hours to the temperature of 325 degrees (Sect. 44) will supply a rough practical guide as to the temperature permissible—the greater the loss, the closer should the lower range of temperatures be adhered to.

[1] The open base-course, or "binder," composed only of crushed stone, coated with pitch or asphaltic cement, extensively and almost exclusively used up to a recent date, is no longer advocated by the best authorities on asphalt pavements. The aim is now to make the base-course as dense and strong as the surface-course.

is dry; nor when the temperature of the air is below thirty-two (32) degrees F., or, if a strong wind prevails, when the temperature of the air is below forty (40) degrees F.

The pavement mixture, whether for base- or surface-course, shall be taken to the street as soon after it leaves the mixer as practicable. When the temperature of the air is below seventy (70) degrees F., the loaded vehicles conveying the mixture to the street shall be covered by canvas covers to prevent the escape of heat. When unloaded upon the street, the temperature of the mass should not be below two hundred and eighty (280) degrees F., and any load or portions of a load found under two hundred and forty (240) degrees F. must be rejected. After being unloaded on the street, the mixture must be shoveled into place in such a manner that the whole of it will be moved from the pile into which it was unloaded.

56. Laying the Base-course.—The base-course will have an average thickness of one and one-quarter (1 1/4) inches after compression. It shall be laid directly upon the pavement foundation, which must be free from all loose fragments and rubbish and be swept clean in advance of the application of the base-course. The base-course mixture shall be spread upon the foundation and evenly and regularly graded to such a depth that after compression by the roller its surface will be .... inches below, and truly parallel to, the pavement datum.

Great care must be taken in handling, spreading and grading the mixture to maintain the uniform admixture of the crushed stone throughout the mass. The rakes used must have tines wide apart, and the back of the rake must be principally used for grading. Immediately after being graded, and while still hot, the base-course shall be rolled with an asphalt roller weighing not less than five tons, the rolling being continued until no further compression takes place.

The base-course must not be laid more than one day's work in advance of the surface-course.

When the base-course is completed it must present a uniform appearance and texture over the whole surface, which must conform so truly to the designed grade and contour that a twelve-foot template, when applied, will show no departure from the true surface greater than one-quarter (1/4) inch.

57. Laying the Surface-course.—In delivering the surface-course mixture upon the base-course, care must be taken not to break or disturb the latter. Any breaks made in the base-course

must be so repaired, before the surface-course is spread, as to be equal in density and surface to the adjoining base.

Before the surface-course is spread the base-course must be thoroughly cleaned and all rubbish, loose material and street dirt removed.

The material for the surface-course shall be so evenly spread and graded with asphalt rakes that after it is properly compacted by rolling, the surface will coincide with the pavement datum within the limits named below. In grading the material, all lumps must be broken up and the whole reduced to a finely comminuted mass of equal density throughout. Directly after being so graded it shall be rolled with a hand-roller, or light steam-roller, to partly compress the material, and, when so directed by the Engineer, the surface shall then be ironed with smoothing irons heated to a temperature that will melt, but not burn, the asphaltic cement. A thin layer of hydraulic cement, just sufficient to prevent adhesion between the material and the roller, shall then be swept over the surface, which shall at once be thoroughly rolled with a ten-ton asphalt roller until the material shall be thoroughly compressed and its surface be brought to the exact grade and contour designed for the street surface. The work of the ten-ton steam-roller must begin before the material has cooled below two hundred (200) degrees F., and be continued until the roller makes no further impression upon the surface. The first course of the heavy rolling shall be parallel to the street beginning at the curb and working toward the center on each side, after which it should be diagonally rolled, and also cross-rolled if the width of the street permits.[1] Any portions of the surface not accessible to the roller shall be tamped with hot tampers until compacted equally with the rolled portion. When completed, the surface shall have an average thickness of .....inches and must be so free from waves or irregularities that a template not less than twelve feet long, when applied to the street surface shall nowhere show a divergence from the designed true surface of more than three-sixteenths (3/16) inch, and a template sixteen (16) feet long applied to the gutters shall show no divergence from the true gutter grade greater than one-eighth (1/8) inch.

[1] The importance of proper and thorough rolling is not usually fully appreciated, and this part of the work is often shirked by the contractor. Not only should the heavy roller be at work as soon as the material will bear it, but the roller should, when work is progressing regularly, be kept at work all the time. It is a safe motto that the final rolling cannot be overdone.

Before the surface-course is placed, all exposed surfaces of curbs, crosswalks, manholes, etc., with which the surface-course will be in contact, must be well painted with hot paving cement or approved pitch. The street shall not be opened to travel until the pavement has become cold and hard.

58. Street Railroad Tracks.—Where railroad tracks exist on the streets, the sub-grade and the pavement foundation shall extend under the tracks, uninterrupted except by the ties and other structures connected with the track. Where concrete foundation is used, special care must be taken with the concrete directly under or around the rails, and concrete made of fine crushed stone and a higher ratio of cement and sand may be required in contact with the rail. The concrete must be thoroughly tamped under and against the rail.

The asphalt surface shall be laid directly against the rails, which, if their temperature be under fifty (50) degrees F., shall be heated by suitable appliances to a temperature of, or above, sixty (60) degrees F. immediately before the asphalt material is placed around the rail. The hot asphalt material must be thoroughly tamped against and along the rail and under any projecting portions of it, and the surface of the pavement must be even with, or slightly (not more than one-eighth (1/8) inch) above the top of the rail. Slot-rails will be treated in the same manner, subject to such modifications as their forms may necessitate.[1]

59. Plant.—The plant for making asphalt paving mixtures must

[1] There is still a wide difference of opinion as to the advisability of laying the asphalt surface directly against the rail, many engineers preferring to set one or more courses of paving brick, or stone paving blocks between the rail and the edge of the asphalt. The writer's experience is to the effect that, if the work is properly done, the first-named form of construction is preferable. If the asphalt be laid against a rail so cold that the asphalt material in contact with or near the rail is chilled before it can be compressed, the work will necessarily be unsatisfactory. As to durability, wheels following the line of the rail or of the paving blocks will sooner or later form a rut in the asphalt which will require repair—and there is not much difference in the results. The attempts to prevent the formation of ruts by setting blocks alternately as headers and stretchers is not always successful, even when the work is well done, and the difficulty of properly compressing the tongues of asphalt between the headers is so great that it is usually not well done. The asphalt settles under travel or is gouged out, leaving a streak of rough pavement, and the difficulty and cost of repairs is considerably increased. When paving blocks or bricks are used, they should be firmly and carefully set in the concrete foundation. Probably the most satisfactory construction of this kind consists of two or three lines of the best paving brick set with their length parallel to the rail. It is somewhat easier to get at and repair rail joints with this construction.

be of approved modern design, adapted to do the work properly, and equipped with efficient machinery. It shall be of sufficient capacity to turn out at least twelve hundred square yards of pavement surface daily without crowding. Weighing and measuring devices shall be accurate and adapted to the purpose, and must be frequently tested and adjusted. Each plant must be supplied with the apparatus necessary to make all determinations and tests required at the plant to properly conduct the work in accordance with these specifications. Steam-rollers must be properly balanced and the rolling surface must be true and smooth. All the street tools used must be of approved kind and quality and must be kept in good working order.

ASPHALT BLOCK PAVEMENT

60. Sub-grade.—The sub-grade for asphalt block pavement shall be prepared as specified in Sect. 26 of these specifications.

61. Foundation.—The foundation for asphalt block pavement shall be hydraulic concrete or broken stone.[1]

Concrete foundation shall be constructed in accordance with Sections 28 to 37 inclusive of these specifications and shall have a thickness of..... .inches.

Broken stone foundation shall be constructed in accordance with Section 40 of these specifications and shall have a thickness, when completed of. .. ..inches.

62. Asphalt Blocks.—Asphalt blocks shall be not less than ten (10) inches nor more than twelve (12) inches long, not less than four (4) nor more than six (6) inches wide and not less than two (2) inches nor more than four (4) inches thick. Blocks for the same street must be of the same standard size throughout and individual blocks shall not vary in any dimension more than three-sixteenths (3/16) inch from the standard size. Blocks that are chipped, cracked or are otherwise defective shall be rejected.

63. Material and Composition.—Asphalt paving blocks shall be

[1] The practice of laying asphalt block pavement upon crushed stone, or a sand foundation, on streets carrying a considerable travel, is inadvisable. See foot-note, page 23.

composed of crushed trap rock[1] or equally hard and durable rock, sand, pulverized stone and asphaltic cement.

The crushed rock shall be of such sizes that all will pass a screen having circular openings one-third (1/3) inch in diameter and that all will fail to pass a number ten (No. 10) sieve. The stone shall be freshly crushed, free from foreign substances and clean and bright.

The sand shall be clean and sharp and of such sizes that all will pass the number ten sieve and not more than five per cent. will pass the number two hundred sieve. The grain-size of the sand shall preferably be such that at least fifty per cent. (50%) of it will pass the number eighty sieve. The screenings from the crushed stone passing the number ten sieve may be used in place of sand, or thoroughly mixed with the sand to produce a mass of the above composition. The pulverized stone shall comply with Section 49 of these specifications. Portland cement shall be used in place of not more than ten per cent. of the whole if directed by the engineer, in which case the Portland cement will be paid for as extra work at the prevailing market price.

The asphaltic cement shall comply with the requirements of Sections 43, 44, 45, 46, 47 and 50 of these specifications.

64. Typical Composition.—A typical composition of the blocks, which must be complied with as nearly as practicable, is as follows; (by weight)

Bitumen	7%
Mineral material passing No. 200 sieve	13%
Mineral material passing No. 80 sieve	9%
Mineral material passing No. 40 sieve	7%
Mineral material passing No. 10 sieve	28%
Mineral material passing No. 3 sieve	36%
	100%

65. Manufacture.—The crushed rock, sand and pulverized stone shall be thoroughly mixed together at a temperature not above three hundred and seventy-five degrees Fahrenheit (375° F.) and not below three hundred and twenty-five degrees Fahrenheit (325° F.) and the asphaltic cement, at a like temperature, added

[1] Hard limestone may be used where trap is not procurable except at a prohibitive cost; but unless the difference in cost is very great the trap will be the most economical in the end.

and the mixing continued until a perfectly uniform mass is produced, with every fragment of stone completely coated with cement.

The hot mixture will then be compressed in molds under a pressure not less than four thousand (4000) pounds[1] per square inch, after which the blocks will be removed from the molds and allowed to cool, either in the air or in water.

The completed blocks after cooling in air shall have a specific gravity of not less than 2.5. They shall not absorb, when immersed in water for twenty-four hours, more than one-half of one per cent. of water. When tested in the standard rattler for testing paving brick the average loss by abrasion shall not exceed twelve per cent. (12%) of their original weight, after 1800 revolutions of the rattler.

66. Laying the Blocks.[2]—The foundation shall be first cleaned of dirt, rubbish or loose material.

When the blocks are four (4) inches or less in depth as laid, they shall be set upon a bed of mortar made and applied to the foundation in the following manner:

The mortar shall be composed of Portland cement and sand, in the ratio of one (1) part cement to three (3) parts of sand, thoroughly mixed with sufficient water to make a rather soft mortar. This mortar shall be spread over the foundation, which shall be previously wetted, in a layer approximately one-half (1/2) inch thick and its top graded by the use of templates to a surface at such depth below, and truly parallel to the pavement datum, that when the blocks are firmly set in it and rammed their tops will be in the true grade and contour of the pavement. The mortar shall be made and spread only as required in the progress of block laying, and any mortar that has begun to set before the blocks are in place and rammed, shall be removed and fresh mortar substituted. The blocks shall be set upon this mortar bed with their longest dimension across the street, in continuous courses which shall be straight and at right angles to the axis of the street. The block layers must stand upon the blocks already laid and not upon the mortar. The blocks and the courses of blocks shall be set as closely together as practicable.

[1] The pressure commonly specified is 5000 lbs per. square inch, but recent investigations make it doubtful if that pressure is ever attained, or is, indeed, practicable with any presses so far constructed.

[2] Asphalt blocks are now very commonly laid upon their sides, even where they are made as thin as two inches, on streets carrying very considerable travel. The practice is not to be recommended unless the blocks are at least four inches thick. Blocks two inches thick will give good service on private drive-ways and streets or quite light travel.

Blocks in adjoining courses must break joint not less than four inches. Whole blocks only will be used, except as fillers at the ends of the courses or in fitting the pavement around manholes or other structures, and where thus used the broken ends of the blocks must be dressed to make close joints. Unless otherwise permitted, each course must be laid continuously across the street without interruption in time. As each course is completed the end joints shall be forced close together by the use of wedges, levers or mauls. Upon the completion of every third course, the courses shall be forced together by placing a timber scantling against the face of the last course and striking it with a sledge or maul. When the blocks are thus laid, and before the mortar under them begins to set, they shall be well rammed to a solid bearing in the mortar with a wooden street rammer weighing not less than thirty (30) pounds, a two-inch plank ten (10) inches wide and three (3) feet long being interposed between the block and the rammer and moved about so that the whole surface shall be covered and rammed. When the ramming is completed, the top of the blocks must conform so closely to the pavement datum that when a template or straight edge is placed upon the pavement, its surface shall nowhere depart from the true surface more than three-sixteenths (3/16) inch. Blocks, or portions of the pavement found too high or too low, must be taken up and reset in fresh mortar to the true grade. When thus completed to the satisfaction of the Engineer, a layer of one-half (1/2) inch of fine dry sand shall be placed over the surface and swept about with brooms until all joints are completely filled. The remaining sand shall be removed from the pavement at such time as the Engineer may direct.

When the depth of the blocks exceeds four (4) inches, they may be set upon a cushion-course of sand, as prescribed for brick pavement, Section 86, the joints to be filled with sand, as specified above in this Section.

67. Railroad Tracks.—Where railroad tracks exist on the street to be paved, the construction shall be the same as prescribed for granite block pavement, Section 78.

68. The street shall not be opened to travel until the mortar under the blocks shall have become fully set, and in no case under five days after the blocks are laid.

GRANITE BLOCK PAVEMENT

69. Granite block pavement shall be laid upon a foundation of hydraulic cement concrete.[1]

70. Sub-grade and Foundation.—The sub-grade shall be prepared as specified in Section 26. The foundation shall be constructed in accordance with the requirements of Sections 28 to 38 inclusive.

71. Granite Blocks.—The blocks shall be made from sound, durable granite, of uniform texture, composition and hardness throughout. No outcrop, deteriorated, soft, brittle, or seamy stone shall be used. If the blocks are obtained from different quarries, or from different parts of the same quarry where the quality or appearance of the rock differs, the product of each must be kept separate and laid together on the street.[2]

The blocks shall be not less than eight (8) nor more than twelve (12) inches long, not less than three and one-half (3 1/2) nor more than four and one-half (4 1/2) inches wide, and not less than four and three-quarters (4 3/4) nor more than five and one-quarter (5 1/4) inches deep.[3] They shall be well-shaped, rectangular, with full edges and corners. Their tops shall not depart more than one-fourth (1/4) inch from a true plane, and their sides shall be dressed so that joints between the courses will nowhere exceed three-fourths (3/4) inch wide, and their ends so that end joints shall not exceed

[1] Granite block pavement is, as a rule, used upon, and appropriate for streets of the heaviest class of travel, and should, therefore, be provided with the best and strongest foundation. It is nearly always poor economy to lay granite blocks upon a broken stone, gravel, or sand foundation.

[2] Like other stones, granite from various localities differs widely in strength, hardness and brittleness. Great hardness, accompanied with comparative brittleness, is not desirable in granite for paving blocks. Such material usually polishes by travel and becomes quite slippery, and it is likely to become "turtle-backed," that is, the corners are likely to be chipped off or worn off, making the pavement very rough and uneven. The quality of the granite to be used in any one city is generally determined by the available supply, and specifications must be drawn with reference thereto.

[3] Except on streets of excessively heavy travel there seems to be no good reason for making the blocks more than five inches deep. Blocks of this depth are quite sure to become deformed by irregular wear before the pavement will need to be renewed.

one-half (1/2) inch wide.[1] The size of the blocks may be varied where necessary to fit the pavement against or around bridge stones or other street structures.

72. Sand Cushion.—The foundation shall be cleaned of all dirt and rubbish. There shall then be spread evenly over it a layer of clean, coarse sand to a uniform depth of one and one-half (1 1/2) inches.

73. Setting the Blocks.—The blocks shall be set in this bed of sand perpendicular to the street surface, with their length at right angles to the street, in courses extending entirely across the street, and at right angles to its axis, except at street intersections where the courses shall be arranged as the Engineer may direct.[2] Only stones of the same width shall be set in the same course. The stones in each course, and in adjoining courses, shall be set firmly against each other. The blocks shall be set in the sand bed in such a man-

[1] The widths of joints here specified as allowable are based upon the assumption that they will be filled with Portland cement grout as specified in Sect. 75. If this grout filling is used narrower joints are not necessary, as the grout has sufficient strength to support the corners of the blocks, and sufficient hardness to resist the wear of travel (largely protected as it is by the blocks themselves) and to cause the blocks to wear down quite evenly.

In many European cities the specifications require much closer joints. The granite there available appears to break out naturally to truer lines and better surfaces than that used in the Eastern states, at least, so that the cost of dressing the blocks abroad is not as great as here.

The City of New York has recently adopted specifications for "Special Improved" Granite Block pavement intended to approximate the Liverpool standard. These require that the blocks shall be not less than 6 nor more than ten inches long, not less than 3 1/2 nor more than 4 1/2 inches wide and five inches in depth. "The blocks are to be rectangular with tops and sides uniform in thickness, to lay closely, and with fair and true surface, free from bunches and so cut or dressed that when laid stone to stone the joints shall not exceed 3/8 of one inch. The head of the block shall be so cut that it shall not have more than one-quarter of an inch depression from a straight edge laid in any direction across the head and held parallel to the general surface of the block." The joints are filled with bituminous cement.

The above specification is very difficult to meet from the granite available to New York without excessive and expensive cutting, and examination of the pavements laid under these specifications shows that the joints greatly exceed the width specified.

It is believed that equally good results may be secured by permitting somewhat wider joints filled with grout, and the cost would be materially reduced.

[2] The most satisfactory arrangement of courses at street intersections is that shown by Fig. 14, page 208, Tillson's Street Pavements and Paving Materials, 2d edition.

ner that their bottom surface shall rest evenly upon the sand and that their tops shall be even with each other and to such an elevation that after the pavement is rammed, as hereinafter directed, its general surface shall conform closely to the pavement datum. Stones in adjoining courses shall break joint not less than three (3) inches.

74. Ramming.[1]—After the blocks are set each individual block shall be thoroughly rammed to give it a firm bearing in the sand and to bring its top to the prescribed pavement datum. The rammers used shall have wooden faces not more than four inches in diameter, and shall weigh not less than thirty (30) pounds. Blocks or sections of blocks whose tops under the ramming remain above or sink below the pavement datum shall be taken up and reset so that after the ramming is completed their tops shall coincide with the pavement datum.

75. Filling the Joints.[2]—After the ramming specified in Sect. 74 shall have been completed, the joints between the paving blocks shall be filled in the following manner:

All the joints for a distance of three feet out from the curbstones, and three contiguous joints continuous across the street, with the included end joints, at intervals of about fifty (50) feet in the length of the street, shall be filled with gravel and bituminous paving cement. The gravel used shall be of such size that all will pass through a screen having five-eighths (5/8) inch meshes, and all will be held on a screen having one-fourth (1/4) inch meshes. When used, the gravel must be free from refuse and street dirt.

[1] The practice of filling the joints with gravel to a depth of one inch or more before the blocks are rammed is of doubtful utility. If the blocks are set closely against each other they will be well held in place while the ramming proceeds. In practice it is hardly possible to closely gage the depth of such preliminary gravel filling, and the top or final filling whether of grout or of gravel and bituminous cement, is likely to vary greatly in depth, and the lateral support of the blocks is thus likely to vary in strength and rigidity.

[2] It has been the almost universal custom, in this country at least, to fill the joints in granite paving either with gravel alone or with gravel and bituminous cement. But the reasons that have led engineers to prefer grout filling for brick pavements apply with equal force to granite pavement. It makes a stronger and harder filling than the gravel and bituminous cement, and gives a better support to the edges of the paving blocks, thus tending to prevent chipping and "turtle-backing" in the pavement. It is also a materially cheaper filling than the gravel and bituminous cement. But to provide for the expansion and contraction of the pavement by changes of temperature, it is desirable that a strip in the gutters, and an occasional strip across the whole street, shall be filled with the more yielding material, as specified.

The bituminous paving cement shall be composed by weight of straight-run coal tar pitch of the hardness commonly known as number six, to which has been added and thoroughly mixed, while both are in a melted condition, twenty per cent. (20%) by weight of refined Trinidad asphalt, or other asphalt, equal for the purpose, and twenty per cent. (20%) by weight of Portland cement. These ingredients must be thoroughly mixed, and kept agitated until used.[1]

The joints will first be filled with the gravel, which shall be perfectly dry, and heated so that when put in the joints it will be at a temperature of about three hundred (300) degrees F. The paving cement, heated to a temperature of about three hundred (300) degrees F., shall be at once, while the gravel is still hot, poured from a spouted vessel into the joints until the interstices of the gravel are entirely filled to the surface of the pavement, repouring being resorted to to accomplish this result whenever necessary.

All the joints in the pavement other than those named above shall then be completely filled with Portland cement grout, in the following manner:

The grout shall be composed of equal parts by volume of sand (Sect. 30) and Portland cement (Sect. 29), a quick-setting cement being preferred. The sand and cement shall be first thoroughly mixed dry and then enough water added to make a grout of such consistency that it will flow like thick cream, and the mixing continued until a homogeneous mass is produced and until the grout is applied to the pavement. The grout shall be prepared in watertight boxes of a convenient size. Before applying the grout the pavement shall be thoroughly dampened by sprinkling. The grout shall be removed from the mixing box and spread over the pavement with scoop shovels, in two courses, the first being sufficient to about half fill the joints, and the second, which shall be applied before the first has begun to set, shall be sufficient to entirely fill the remaining space in the joints. As the grout is applied to the pavement it shall be swept about with brooms until it all enters the joints.

[1] The object of adding asphalt and Portland cement is to make the cement stronger and less susceptible to changes of temperature. Pure coal-tar pitch is very brittle at low temperatures, and is liable to flow from the crown of the street to the gutters in hot summer weather. A cement made as here specified is not only much stronger and less brittle in cold weather, but requires a materially higher temperature to cause it to flow than does pure pitch.

76. Order of Work.—The sand bed shall not be put in place more than fifty (50) feet ahead of the block setters. The ramming and filling of the joints shall follow closely the block setting, but no ramming shall be done within less than six (6) feet of the face of the block setting; and the final joint filling shall be kept completed to within twenty-five (25) feet of the ramming; except that all the work rammed during any day shall have the joint filling completed before the cessation of work on that day. The street shall not be opened to travel until the grout has thoroughly set.

77. Fitting Paving Around Other Structures.—The size of blocks and the width of courses shall, as the block laying approaches bridge stones, curbs and other structures, or in making closures with other sections of pavement, be so selected and adjusted that joints not over three-quarters (3/4) inch in width shall result, without breaking blocks or splitting courses.

78. Street Railroad Tracks.—Where railroad tracks exist in the street the paving blocks shall be laid against the rail in the following manner:

The sub-grade and the pavement foundation shall extend under the rails uninterrupted except by the ties or other structures connected with the railroad track. For a distance of sixteen (16) inches, on each side of the rail, measuring from the center thereof, there shall be spread on the pavement foundation a layer of mortar not less than one and one-half (1 1/2) inches thick, composed of one (1) part of cement and three (3) parts sand, complying with the requirements of Sections 29 and 30. Upon this layer of mortar shall be set, against the rail, and on each side of it, selected paving blocks, securely bedded in the mortar before it shall have begun to set.[1] Alternate blocks shall be long and short so as to break joint with the blocks of the adjoining pavement. Selected blocks with well dressed top surfaces shall be used and their tops shall be set as nearly as practicable at the level of the top of the rail, but not so high that the car wheels will ride upon them. In setting the blocks they shall be firmly bedded into the mortar by the use of paving hammers, but they shall not be thereafter rammed. As the blocks are set, any space between the paving blocks and the web of the rail shall be filled with mortar of the quality described above. The

[1] As the wheels of vehicles frequently follow along the lines of the rails, thus concentrating their effect on a narrow strip near the rails, and as the continuous joint against the rail makes the pavement weaker there, the mortar bed, and the greater care in setting the blocks along and near the rail are advisable.

placing of these blocks shall not precede by more than ten (10) feet the block laying on the street. Care must be taken not to disturb the bedding of these blocks in the laying of the adjoining pavement, or otherwise. The joints shall be filled with grout as specified in Sect. 75.

The construction along slot-rails shall be the same as described above, except that blocks of special size or shape may be required, as the Engineer may direct.

79. Bridge Stone Crossings.—Where directed by the Engineer, the old bridge stone shall be redressed and relaid, as hereinafter specified for new bridge stone, and shall be moved from the point where taken up to the point where they are to be relaid, by the Contractor at his expense.

New bridge stone shall be of the same quality of granite as the paving blocks and free from imperfections. They shall not be less than three and one-half (3 1/2) nor more than six (6) feet long, eighteen (18) inches wide and of a uniform thickness not less than six (6) nor more than eight (8) inches, but these dimensions may be varied by the Engineer where necessary to fit the stone into special locations.

Their top shall be well dressed to a true plane surface not varying in evenness more than one-quarter (1/4) inch. The sides shall be dressed perpendicular to the face so as to joint closely against the paving blocks. The ends shall be cut to lines making an angle of from 60° to 45° with the longitudinal axis of the stones[1] and so dressed and to such a bevel that when set in the curved surface of the street, the joint between adjoining stones shall not be wider than three-eighths (3/8) inch from top to bottom.

Bridge stones shall be set in advance of the block laying, over the concrete street foundation, in a bed of sand or gravel in which they thall be firmly bedded. Their upper surface shall conform truly so the pavement datum. They shall be set accurately to the lines given by the Engineer. Where the crosswalk requires more than one width of bridge stone, the courses shall be laid parallel to, and at such distance from each other as the Engineer may direct, and the space between courses shall be filled with paving blocks laid as specified for other parts of the street.

[1] If the joints are parallel to the direction of travel on the street the wheels of vehicles are more likely to abrade or break off the corners of the stone and form incipient ruts.

BRICK PAVEMENT[1]

80. Sub-grade.—The sub-grade for brick pavement shall be prepared in accordance with Sect. 26, and shall be finished to a surface .....inches below and parallel to the pavement datum.

81. Foundation.—The foundation for brick pavement shall be of hydraulic concrete[2] prepared in accordance with Sections 28 to 37 inclusive. Its thickness shall be.....inches and its upper surface shall, when completed, be parallel to and at a depth below the pavement datum equal to the depth of the brick plus one and one-fourth (1 1/4) inches. The surface of the foundation shall not vary more than one-half (1/2) inch above or below that depth.

82. Paving Brick.—The linear dimensions of paving brick may vary between the following limits: In length, from eight and one-half (8 1/2) to nine and one-half (9 1/2) inches; in width, from two and one-fourth (2 1/4) to three and one-half (3 1/2) inches; in depth, from four (4) to four and one-eighth (4 1/8) inches; but the length shall not be less than two and one-half (2 1/2) nor more than three and three-fourths (3 3/4) times the width.[3] The corners shall all be rounded off to a radius of not less than one-eighth (1/8) nor more than three-sixteenths (3/16) inch. The brick for any one contract shall be all of the same kind and of the same standard size, and the individual bricks shall not vary in length more than three-sixteenths (3/16) inch, nor in width more than one-eighth (1/8) inch from the size adopted as standard. Raised lugs or letters are permissible on one side of each brick but must not project more than three-sixteenths (3/16) inch from the general surface.[4]

[1] These specifications conform in most particulars to those adopted by the "Association for Standardizing Paving Specifications," and are substantially the same as those recommended by the "National Paving Brick Manufacturers' Association" though they differ in some details from each. The latest specifications adopted by the Association for Standardizing Paving Specifications are very full and satisfactory and are to be highly commended.

[2] Here again a good concrete foundation is recommended, as being in the end the most satisfactory and economical. See foot-note, page 23.

[3] The Association for Standardizing Paving Specifications (New Orleans meeting) adopted a standard size for paving bricks and blocks as follows: Paving brick, 8 1/2 inches long, 2 1/2 inches wide and 4 inches in depth. Paving blocks 8 1/2 inches long, 3 1/2 inches wide and 4 inches deep. There seems to be no sufficient reason for confining the brick to these dimensions.

[4] The specifications of the Association for Standardizing Paving Specifications require that all paving brick shall have lugs on one side, and allow a projection

The brick must be specially manufactured for paving purposes. They may be made from shale or from suitable clay. In either case the material must be thoroughly pulverized, mixed and tempered, and must be free from lime nodules or other substances that may disintegrate the brick when immersed in water. The brick shall be molded in efficient brick machines to a truly rectangular form, free from cracks, flaws and injurious laminations. After being dried the brick shall be properly and uniformly burned in down-draft kilns. Shale brick shall be burned to the point of incipient fusion or vitrification. After the burning is completed, the brick shall be allowed to cool with sufficient slowness to insure thorough annealing.

The completed brick shall be free from flaws, cracks, ragged corners, and from such distortion or warping as will interfere with their utility or good appearance in the pavement. Paving brick shall not be salt-glazed.

83. The brick shall be subjected to the following tests to determine their quality:

When broken by the blows of a hammer the brick shall be strong and tough. The broken surface shall show a homogeneous composition throughout the broken section, free from flaws, injurious laminations, nodules and voids, and shall appear to be uniformly burned from surface to center.

When subjected to the standard "Rattler" test, in accordance with the rules adopted by the National Paving Brick Manufacturers' Association, the average loss in weight shall not exceed eighteen (18) per cent [1] and the loss in weight of any individual brick in the test shall not be more than twenty-five (25) per cent. greater than the average loss of the whole charge.

When subjected to the absorption test, in accordance with the rules adopted by the National Paving Brick Manufacturers' Association, shale bricks shall not absorb more than two (2) per cent. nor

of 1/4 inch from the face of the brick. The object is to provide a wider joint between the bricks in order to facilitate the filling of the joints. The author does not believe these lugs necessary, nor that brick without lugs, but otherwise acceptable, should be excluded. It is certain that many of the best brick pavements ever constructed have been built of bricks without lugs. If lugs are required they should preferably not project more than one-eighth inch. The same reasons that make narrow joints desirable in other block pavements apply equally to brick pavements.

[1] The A. S. P. S. Specifications permit a loss of 22% with the block size, but do not name a permissible loss for "brick" size.

less than one-half (1/2) of one per cent. of their weight of water,[1] and clay bricks shall not absorb more than six (6) per cent. of their weight of water; the absorption of any individual brick shall not be more than fifty (50) per cent. greater than the mean absorption of the whole lot tested.[2] Brick that do not successfully pass all these tests will not be accepted.

84. Samples.—Where samples of paving brick have been required and submitted by successful bidders, and tested as described above, it will be assumed that these samples fairly represent the quality of the brick to be subsequently supplied for the work, and brick that do not come up to the standard thus established will not be accepted.

85. Delivering Brick on Street.—Unless the sidewalks are too narrow to permit of it, the brick shall all be delivered upon the street before the foundation is constructed, and neatly piled upon the outer edge of the sidewalks; occasional openings being left in the piles for the accommodation of foot passengers. One-half the brick required shall be thus delivered and piled upon each sidewalk. In delivering the bricks from these piles to the bricklayers, they must be carried on pallets, or other suitable devices must be used to prevent mutilation by rough handling; they must not be dumped from wheelbarrows upon freshly-laid brick pavement.

If for any reason the bricks are not delivered before the foundation is laid, or if the sidewalks are too narrow to permit of the brick being stored upon them, they may be delivered over the foundation, but not until the concrete has set so hard that it will not be injured by transportation over it.

86. Sand Cushion.—Directly before the brick are laid into the pavement there shall be spread over the foundation a layer of sand one and one-half (1 1/2) inches in depth. The sand shall be free from vegetable or other refuse matter, and shall not contain more than five (5) per cent. of clay and loam. Pebbles and fragments of stone exceeding one-fourth inch in diameter must be screened out. When spread on the street the sand shall be sufficiently dry to permit of proper gaging by templates, as hereinafter described. The sand shall be spread and correctly gaged to the proper thickness and surface by the use of templates formed to the true designed

[1] Absorption of less than one-half of one per cent., usually indicates that a shale brick has been over-burned, resulting in increased brittleness.

[2] The absorption test is falling into disfavor, particularly with the manufacturers. The author believes that it possesses a distinct value and should be retained.

cross-sectional contour of the pavement. If the width of the street between curbs does not exceed twenty-five (25) feet, the template shall be made in one length sufficient to cover the full width of the street, and its ends shall be so constructed and fitted with iron rollers, that it will rest upon and roll along the top of the curb at each end; if the width of the street between curbs be not more than fifty (50) feet, the template shall be of sufficient length to reach from the curb to the middle of the street, and constructed to move on rollers on top of the curb at one end and upon a plank six (6) inches wide and one and one-half (1 1/2) inches thick laid upon the foundation along the center line of the pavement. The template shall be worked forward and backward along the line of the street until the surface of the sand conforms exactly to the designed contour of the pavement, at a depth below the pavement datum equal to the depth of the paving brick minus one-fourth (1/4) inch. The whole surface shall then be rolled with a garden roller not less than thirty-six inches long and not less than thirty inches in diameter, weighing not less than three hundred pounds. When completed the surface of the sand cushion shall be smooth and unbroken, and care must be taken not to disturb it before the bricks are set upon it.

87. Setting the Brick.—Several courses of brick, aggregating a strip having a width of not less than twelve (12) inches nor more than fifteen (15) inches on each side of the street, beginning against the curb, shall be first laid; the brick being set with their long dimension parallel to the curb.[1] The pavement intervening between these gutter courses will then be set in courses at right angles to the axis of the street, except in street intersections, where the courses shall make an angle of forty-five (45) degrees with the axis of the street. The brick shall be set upon edge on the sand cushion with their top faces parallel to the pavement datum, in straight courses, continuous across the street, the long dimension of the brick being parallel to the courses; they shall be set as closely together as possible, so that the joints both between the courses and between individual bricks shall not exceed one-eighth (1/8) inch, where the bricks are without lugs, and not more than one-fourth inch where the brick have lugs. Broken bricks and bats shall not be used except as closers at the ends of the course and in fitting the pavement around manholes, etc., and nothing smaller than half-bricks shall be used in either case, and the broken ends must be shaped to make reasonably

[1] The object of this is to make a gutter offering less obstruction to the flow of water.

close joints. Filling up with bats must follow the brick-laying closely. Brick with lugs shall be laid with the lugs all in one direction.

88. Inspection.—After the bricks are laid the pavement will be inspected by the Engineer, or his agent. He may require that the surface shall be previously wetted by sprinklers, or by a sprinkling nozzle, in order to detect soft or porous bricks.[1] Defective bricks indicated by him shall be removed and replaced by acceptable brick.

89. Rolling and Ramming.—The surface of the pavement shall then be rolled and rammed in the following manner:

The roller used shall be of the asphalt roller style, driven by steam and weighing not less than three and one-half (3 1/2) nor more than five (5) tons. The rolling shall begin as near the curb as practicable, the roller being operated slowly, parallel to the axis of the street, and working outwardly until the center of the street is reached, when the roller will proceed to the opposite side of the street and the operation proceed as before. After this longitudinal rolling is completed the pavement will be continuously rolled a second time, the roller operating back and forth at an angle of forty-five degrees to the axis of the street, and a third time, the roller operating at right angles to the course of the second rolling. After the rolling is thus completed the brick in the gutters not reached by the roller shall be rammed with a street rammer weighing not less than thirty (30) pounds, a plank not less than four (4) feet long, ten (10) to twelve (12) inches wide and two (2) inches thick being interposed between the pavement and the rammer and moved about so that the whole surface of the gutter shall be thoroughly and equally rammed and its surface brought to an even junction with the rolled portion of the work.

When the rolling and ramming is thus completed the surface of the pavement shall conform so truly to the designed pavement datum that it will nowhere depart more than three-sixteenths (3/16) inch from properly formed templates and straight-edges applied to its surface.

90. Filling the Joints.[2]—Directly after the completion of the rolling

[1] This is the simplest and most effective way to detect soft and underburned brick.

[2] *If the joints are to be filled with bituminous cement,* substitute for sections 90 and 91 the following:

Directly after the completion of the rolling and ramming all the joints in the

and ramming, the joints between the bricks shall be filled as follows:

The joints in the longitudinal gutter courses, and the joints between six contiguous courses running across the street, from gutter to gutter, in each length of fifty (50) feet of the pavement, shall be filled with bituminous cement composed of coal-tar pitch, commercially known as Number Four, to which has been added twenty (20) per cent. of refined Trinidad asphalt and twenty (20) per cent. of hydraulic cement, all by weight. In preparing this bituminous cement, the pitch shall first be melted and the asphalt, also melted, added and thoroughly incorporated by agitation. The hydraulic cement shall then be added and the whole agitated until a complete and uniform mixture results. The bituminous cement thus prepared shall while sufficiently hot and liquid to flow freely, be poured from a spouted vessel into the joints until they appear to be nearly or quite full. After allowing time for the filling to subside, the joints will be gone over a second time and completely filled.

All the remaining joints in the pavement shall be filled with Portland cement grout, as follows:

The grout will be composed of equal parts by volume of sand (Sect. 30) and Portland cement (Sect. 29), a quick-setting cement being preferred. The sand and cement shall be first thoroughly mixed dry and then enough water added to make a grout of such consistency that it will flow like thick cream, and the mixing continued until a homogeneous mass is produced and until the grout

brick pavement and between it and the curbing, manholes or other structures, shall be filled with a bituminous cement in the following manner:

The bituminous cement shall be composed, by weight, of one hundred (100) parts of straight-run coal-tar pitch commercially known as number four and twenty (20) parts of refined Trinidad asphalt melted and thoroughly mixed together at a temperature of about 350° F., to which shall be added twenty (20) parts of dry Portland cement, which shall be thoroughly incorporated with the hot bitumen until a homogeneous mass is produced, and kept agitated so as to prevent settlement or separation until the cement is used. If another asphalt is used instead of Trinidad the quantity added to the pitch must be sufficient so that the cement will not flow at a temperature lower than one hundred and twenty-five degrees Fahrenheit (125° F.). This cement while at a temperature of about 325 degrees F. shall then be poured from a spouted vessel into all joints and vacancies in the pavement until they are completely filled, repouring being resorted to if necessary to accomplish the complete filling of the joints. After the joints are thus filled a layer of sand one-half inch thick will be spread over the whole surface of the pavement and allowed to remain until the engineer shall direct its removal.

is applied to the pavement. The grout shall be prepared in water-tight boxes of a convenient size. Before applying the grout the pavement shall be thoroughly dampened by sprinkling. The grout shall be spread over the pavement with scoop shovels, in two courses, the first being sufficient to nearly fill the joints, and the second, which shall be applied before the first has begun to set, shall be sufficient to entirely fill the remaining space in the joints. As rapidly as the grout is applied it shall be swept with brooms until it all enters the joints.[1]

91. Travel must be excluded from the pavement until the grout has set firmly; in no case less than five days, and the grout must be kept moist during this period.

WOOD-BLOCK PAVEMENT

92. Sub-grade.—The sub-grade for wood-block pavement shall be prepared as specified in Section 26, and shall be finished to a surface.....inches below the pavement datum.

93. Foundation.—The foundation for wood-block pavement shall be Portland cement concrete.....inches thick, prepared as specified in Sections 28, 29, 30, 31, 32, 33, 34, 35, 36 and 37. The upper surface of the concrete foundation, when completed, shall be at a distance below the pavement datum equal to the depth of the blocks to be laid, plus one-half (1/2) inch, and must not vary more than one-fourth (1/4) inch above or below that depth.

[1] The bituminous-cement joints are principally for the purpose of providing for the expansion of the pavement in very hot weather.

Experience seems to have proved that cement grout is, everything considered, the best and cheapest filling for the joints in brick pavement. If the filling is properly done, the edges of the brick are supported and the corners do not chip off. With the expansion joints provided at intervals by the bituminous-filled joints, the curbs will not be forced out of line, nor will the pavement be raised from its sand bed by expansion, causing the rumbling sound sometimes noticed.

Where grout filling is used there seems to be no necessity for covering the surface of the pavement with sand, as is usually done, provided the grout is kept damp.

MATERIALS

94. Wood-blocks.—The wood-blocks may be made of Long-leaved yellow pine (Pinus palustrus), Lob-lolly pine (Pinus tæda), Short-leaved pine (Pinus echinata), Cuba pine (Pinus heterophylla), Black gum (Nyssa sylvatica), Red gum (Liquidambar styraciflua), Norway pine (Pinus resinosa), or Tamarack (Larix laricina), or of other species of wood of equal strength and toughness and of a texture permitting as satisfactory preservative treatment as those herein named. But, as far as practicable, only one species of wood shall be used on any one contract.[1]

[1] Since immunity from early natural decay is secured by preservative treatment, the important requisite for wood paving blocks is capacity to withstand the wear and tear of the travel on the street. We have as yet no very satisfactory data as to the ability of the various species of wood to endure the somewhat peculiar and special duty to which paving blocks are subjected.

The test which seems to most nearly approach to what is wanted is that of crushing strength, when the force is applied to the end of the sample, parallel to its fibers; but this does not embrace the effect of impact to which paving blocks are subjected under street travel. Whether this may be considered a function of the end-crushing strength or not is an open question, though there seems good reason to believe that it will prove to be so; and if so, there is no good reason why woods of substantially equal strength under the end-crushing test should not show about the same endurance under street travel, independent of the element of natural durability, which is practically eliminated by preservative treatment.

The end-crushing strength per square inch of some of the kinds of timber named as acceptable is about as follows:

Southern long-leaved yellow pine	6900 lbs.
Lob-lolly pine	6500 lbs.
Short-leaved pine	5900 lbs.
Cuban pine	7900 lbs.
Norway pine	6700 lbs.
Red gum	7100 lbs.

It was formerly very customary to specify that only Southern long-leaved yellow pine might be used for paving blocks, though this requirement was seldom strictly enforced. The fact is, that with the exception of the test based upon the number of growth rings per inch, it requires an expert knowledge, acquired only by long experience, to distinguish with certainty the species of Southern pine from the appearance of the lumber alone. It is now almost impossible to obtain in the market shipments of strictly long-leaved yellow pine, and while that wood is undoubtedly superior to the other pine timbers for paving blocks it seems useless to specify its exclusive use, or to propose specifications designed to exclude lumber made from other species of pine. It was doubtless the recognition of this situation that influenced the Association for Standardizing Paving Specifications, at its last (New Orleans) convention to adopt a specifica-

Only wood from live, sound trees shall be used. The lumber from which the blocks are cut shall be properly manufactured, free from bark, and with full square corners. It shall be free from decay, dotiness, brashness, shakes, large season cracks, loose or unsound knots over three-fourths (3/4) inch in diameter, and all other imperfections which may, in the opinion of the Engineer, be detrimental. "Fat" pine containing so much resin that it will not take up the specified quantity of creosote oil in treatment may be rejected. Second-growth timber, and Southern pine showing, outside of a radius of three (3) inches from the heart, nine (9) or less annual growth rings to the inch, will not be accepted.

The paving blocks made from the lumber hereinbefore specified shall be well manufactured and truly rectangular and square edged. Their depth (parallel to the fiber) shall be.....inches,[1] their length shall not be less than six inches nor more than three times their depth, and their width shall be from two and one-half (2 1/2) to three and one-half (3 1/2) inches, but at least one-fourth inch less than their depth.

tion which practically admits everything known in the market as "Southern yellow pine" having annual growth rings averaging less than eight to the inch and excluding all timber having less than six rings to the inch. Within these limits these specifications practically admit all pine lumber shipped from Southern mills.

The specifications here proposed, by limiting the number of growth rings to nine per inch, would not confine the lumber to true long-leaved yellow pine, but would secure a more mature and solid quality of lumber. It is true, however, that both these specifications and those adopted by the A. S. P. C. exclude most "Cuban pine" lumber which is very rapid growing, the growth rings often numbering but three or four to the inch, though the strength of the wood from this species indicates that it may safely be used for pavement.

[1] The question of the most economical depth for wood paving blocks is as yet unsettled. In New York City, blocks 3 1/2 inches in depth are adopted as the standard and are being used on streets of the heaviest travel, the practice of Berlin, Paris and other foreign cities being thus followed. The arguments in favor of these short blocks are lower first cost, and that, with much deeper blocks, the usual uneven wear of a wood pavement will make it so rough as to require removal before the blocks are worn down so as to be split up and dislodged from their places. While reliable data on these points are wanting, it seems to the writer very unwise to use such short blocks on streets of heavy travel, and he would recommend that the minimum length for use on such streets be 4 1/2 inches, and he would prefer 5 inches.

On streets of light travel a length of 3 1/2 inches should be satisfactory.

Recent observations on heavy travelled streets in New York indicate that when long-leaved yellow pine blocks become worn down to a remaining depth of about 2 1/8 inches they split up into fine slivers and the pavement goes to pieces.

All the blocks for any one contract shall be of the same standard depth and width, and the individual blocks shall not vary more than one-eighth inch from the designated depth and width.

95. Creosote Oil.[1]—The oil used for the preservative treatment of the paving blocks shall be coal-tar creosote oil, commonly known as dead oil of coal tar, without admixture or adulteration with other oils or tars. Oils produced or resulting from the distillation of water-gas tar, blast-furnace tar, producer-tar, lignite-tar, petroleum-oil tar, or wood-tar, or, containing an admixture of any of these will not be accepted. The creosote oil shall not contain more than five per cent. (5%) of tarry matter nor more than two per cent. (2%) of water. Its specific gravity at a temperature of 100° F. shall be not below 1.03 nor above 1.08. Not less than ninety-nine per cent. (99%) shall be soluble in hot benzol. It shall not contain more than eight per cent. (8%) of tar acids. When two hundred (200) grams are subjected to distillation at gradually increasing temperatures, not more than five per cent. (5%) of distillate shall distil over up to a temperature of four hundred degrees F. (400° F.), nor more than thirty-five per cent. (35%) shall distil over up to a temperature of four hundred and fifty-five degrees F. (455° F.), and not more than eighty per cent. (80%) shall distil over up to a temperature of six hundred degrees F. (600° F.). After complete distillation there shall not remain more than two per cent. of coke. The residue remaining, upon sulphonating a portion of the total distillate, shall not exceed one per cent. (1%). The above tests shall be made in accordance with the methods prescribed in the "Report of the Committee on Preservative Treatment of Poles and Cross-arms" of the National Electric Light Association, 1911.

96. Preservative Treatment.—The paving blocks shall, after

[1] Most of the more recent specifications require the use of a heavy oil, said to be composed of creosote oil with an admixture of refined tar, on the ground that the tar is necessary as a water-proofing agent to prevent the creosote oil from being dissolved out by water or evaporated into the air. It is claimed that if moisture can thus be excluded from entering the wood, decay will be prevented, even in the absence of the antiseptic elements of creosote oil. It is not intended to discuss this matter at length here. We know from long experience that genuine creosote oil is the best preservative of wood so far found; also that creosoted piles have stood in tidal waters, alternately exposed to water and air, for twenty-five years and still retain sufficient creosote oil to resist the Teredo—a very severe test. Why experiment with a comparatively untried material, particularly when it costs as much as the genuine creosote oil, is rather more difficult to force into the wood, and has some admitted objectionable qualities?

they are cut to the proper dimensions, be subjected to preservative treatment with the creosote oil specified in Section 95.

The contractor may employ any of the standard methods in common use for impregnating the blocks, provided that uniform results are attained, complying with the following requirements:

The wood shall not be heated during any part of the process to a temperature exceeding two hundred and sixty degrees Fahrenheit (260° F.).

All parts of every block shall be reached and penetrated by the oil. The quantity of oil found in the blocks after treatment shall average not less than..... .pounds per cubic foot of wood.

The oil in the treating tanks during the process of impregnation shall not become diluted with water to the extent of more than five per cent. (5%) and if the percentage of water in the oil during the process of treatment shall exceed two per cent. (2%) the quantity of the oil to be injected in the wood as stipulated hereinbefore shall be increased in a like ratio; for example, if the oil in the treating tanks shall be found to contain four per cent. (4%) of water the quantity required to be found in the blocks after treatment shall be four per cent. (4%) greater than herein specified.

The quantity of oil injected shall be determined primarily by tank measurements, but shall be verified by actual determination of the quantity of oil in the treated blocks by the following method: representative treated sample blocks shall be selected and an auger hole one inch in diameter bored entirely through the block parallel to the fiber, the borings all collected, thoroughly mixed, and the quantity and ratio of oil to wood in the borings determined by extracting the oil completely with carbon disulphide. The center of the auger hole shall be located midway between the sides of the block and at a distance from the end of the block equal to one-third (1/3) of the length of the block. At the time of treatment the blocks shall not be green or saturated with water, but they shall, preferably, not be thoroughly seasoned. After treatment, and until used, the blocks shall, during dry weather, be frequently well drenched with water to prevent excessive drying out and cracking

97. Laying the Wood Blocks.—The concrete foundation shall be cleaned and swept to remove all dirt and débris and shall be thoroughly dampened immediately in advance of the setting of the blocks. Upon the concrete foundation shall be spread a layer of mortar about one-half inch thick, made of one part Portland cement and two parts sand with sufficient water to make a moderately stiff

paste.[1] The mortar shall be thoroughly mixed and shall be spread in place over the concrete foundation immediately in advance of setting the blocks to such a thickness that when the blocks are set and properly tamped their tops shall conform accurately to the pavement datum.

Upon this mortar bed the blocks shall be set with their fiber vertical, in straight, parallel courses at right angles to the axis of the street, except at street intersections where they shall be set at an angle of forty-five degrees with the axis of the street. The blocks shall be set as close together as practicable. Blocks in adjoining courses shall break joint at least three inches. Blocks of such lengths shall be selected as to make as little splitting as practicable in filling out ends of courses. Where splitting is necessary, no fractional block shall be used whose length is not at least equal to its width.

After the blocks are thus set the whole surface of the pavement shall be rammed with a rammer weighing not less than twenty pounds, a plank ten (10) inches wide, two (2) inches thick and four feet long being interposed between the rammer and the pavement and moved about as the ramming progresses until the blocks are forced into a firm seat in the mortar bed and their tops brought accurately to the pavement datum. The ramming shall be completed before the mortar under them has begun to set, but no ramming shall be done, during the progress of the work, nearer than three feet to the edge of the block-setting, except where the block-setting may be suspended, as at the end of the day's work, when all the blocks then set shall be rammed.

The top surface of the pavement when completed shall conform so truly to the pavement datum that correctly formed templates twelve (12) feet long applied to the surface shall show at no place a departure of more than three-sixteenths (3/16) inch therefrom.

[1] It is a common practice of contractors in some cities, in the laying of both wood-block and asphalt-block pavement, where a mortar bed is called for, to substitute a bed of mixed sand and cement, dampened only to such a degree as will make the mass pulverulent like damp sand, the claim being made that ordinary mortar cannot be spread and gaged properly. This claim is unfounded. The objection to the practice is that the dampened mixture does not contain sufficient water to cause the cement to set, and with the practically water-tight paving surface, does not receive, even in rainy weather, the necessary amount of water. If the weather be dry, the small quantity of moisture in the mixture quickly evaporates, leaving the so-called mortar bed not much better than a layer of sand alone. The writer has found such alleged mortar dry and unset two weeks after the pavement had been completed. If real mortar is not to be used, a layer of sand might almost as well be substituted at first.

98. Filling the Joints.—After the block setting is completed, perfectly dry, fine sand shall be spread over the pavement surface and swept about until every joint into which the sand will penetrate shall be completely filled. The remaining sand shall be left upon the pavement for such time as the Engineer may direct, when it shall be removed by the Contractor.[1]

99. Inspection.—The lumber for paving blocks will be inspected before it is cut into blocks. The blocks will also be inspected upon delivery to the street and as they are laid. Blocks that have, in treatment or subsequent handling, developed open season cracks or wind shakes or other imperfections that may prevent their durability or usefulness in the pavement shall be rejected and removed from the street.

100. Chamfered Blocks.—Where wood-block pavement is laid on streets or parts of streets having a gradient of more than 3%, the blocks shall not be less than four (4) inches long, and the upper side-corners of the blocks shall be chamfered to a depth of three-eighths (3/8) inch, the chamfered surface to make an angle of 40 degrees with the vertical sides of the blocks; or such other construction shall be used as will, in the opinion of the Engineer, provide an equally good foot-hold for horses.

101. Expansion Joints.—Before the blocks are set there shall be placed along and against each curb a board of tropezoidal section having a width one inch greater than the depth of the blocks, the upper edge of which shall have a thickness of three-eighths (3/8) inch for each ten feet or fraction thereof of the width of the street between curbs, and a bottom width one-fourth (1/4) inch less than the top. The paving blocks at the beginning and end of each course shall be set against this board. After the ramming of the blocks has been completed, these boards shall be carefully

[1] In a number of cities the specifications require the joints in wood-block pavement to be filled with Portland cement grout. If the blocks are set as closely together as they should be, the joints will be so narrow that no grout, thick enough in consistency to be of value, will enter them, except for a short distance down from the top, the remaining depth of the joints remaining unfilled. An examination of any well-laid wood-block pavement soon after it has been attempted to fill the joints with grout will verify this statement. Furthermore, the oil which exudes from the blocks, acting on the thin films of grout, seems to deterioriate the mortar and to render it practically inert. On the contrary, fine dry sand will readily run into and completely fill the joints, and under travel the joints will soon become impervious to water. The sand filling is therefore regarded as better, and it costs less than the grout filling.

withdrawn and the space between the curbs and the paving blocks shall be completely filled with the bituminous paving cement described in Section 90.

102. The street shall not be opened to travel until such time as the mortar under the blocks shall have become well set, nor until the Engineer shall so direct.

BITUMINOUS CONCRETE PAVEMENT

Note.—The phrase, Bituminous Concrete Pavement, has been applied to a large variety of roadway surfaces differing materially from each other in composition, construction and utility. Some of these are covered by United States patents, the scope and limitations of which are not yet fully determined or understood. The necessity of avoiding infringement of these patents has to be kept in mind in framing specifications for public use, and this consideration does not permit the presentation here of specifications which, in the opinion of the author, would secure an ideal pavement of this general character.

Bituminous concrete pavements constructed in substantial conformity with these specifications have been laid on a number of city and town streets and country roads and have proved satisfactory and fairly durable in use. It is believed that they do not infringe any existing patents.

Our rather limited experience with pavements of this character seems to indicate that if good materials are used and the work properly done, they are suitable for use on city streets of light travel, and on suburban streets and country roads carrying an amount of travel considered heavy for these classes of roadways. Where the results have been unsatisfactory, the cause can generally be traced to unsuitable materials or unskillful construction, the result of ignorance or carelessness on the one hand, or of the attempt to reduce first cost below normal figures on the other. Many people are searching for a pavement or roadway that will have all the good qualities of the standard pavements but can be built about as cheaply as a common macadam road. It is possible that something of the kind may be discovered; but in the present state of the art it is chimerical. High quality and low first cost do not go together in street paving. The question to be considered is, rather, how can we invest a dollar in street or road building so that it will, in the long run, yield the best return upon the investment. The pavement provided for in these specifications is not a cheap pavement, but where it is suitable for the conditions to be met, it will be well worth its cost.

SPECIFICATIONS

103. Sub-grade.—The sub-grade except where old pavement is utilized for foundation shall be prepared in accordance with Section 26 of these general specifications.

104. Foundation.[1]—The foundation for bituminous concrete pavement shall be a properly prepared old pavement, or hydraulic concrete, or compressed broken stone, as determined by the engineer.

105. Old macadam pavement or road to be utilized for foundation, shall be prepared in the following manner:

All high places or humps shall be dressed down to a plane two (2) inches below the pavement datum, the work being done with care so as to disturb as little as possible the macadam that is to remain. Depressions in the old macadam shall be carefully cleaned out so as to remove all earth and other débris and loose material, and filled with hydraulic concrete. Newly dug or filled trenches and holes extending through the macadam shall be excavated and cleaned out so as to admit the use of at least four (4) inches of hydraulic concrete. The hydraulic concrete for thus leveling up the roadway shall be composed of one (1) part of approved Portland cement, four (4) parts of clean sand and nine (9) parts of sound, hard crushed stone, well mixed into a wet concrete. After placing, the concrete shall be well tamped so as to form a compact body, conforming to a plane two (2) inches below the pavement datum. The concrete shall be protected from travel and allowed to become well set before the surface of bituminous concrete is applied.

106. Old stone-block or brick pavement may be utilized for foundation, provided that the blocks or bricks do not require to

[1] Wherever an old pavement or macadam road can be utilized it makes an excellent foundation for a pavement of this kind, provided it is not in too dilapidated a condition, extends from curb to curb, and its surface conforms near enough to the desired street surface so that the necessary changes and repairs will not be too expensive. Where the new pavement is expected to carry quite a heavy travel it is not advisable to use plain crushed stone for filling depressions and leveling up the surface. It is difficult, even where proper care is used, to make such patches of broken stone as firm and strong as the adjoining old pavement, which is a necessary condition to secure satisfactory results; for if the masses of broken stone yield under travel, slight depressions will form over them in the bituminous surface, which will in time become holes requiring repairs. The 1 : 4 : 9 concrete specified for this work is not very much more expensive than plain broken stone, it will not shift or break up under travel, and will in the end prove a better investment.

be taken up and reset, or, if so taken up and reset, that the joints shall be completely filled with grout composed of one (1) part Portland cement and two (2) parts of good sand. Depressions, trenches and holes shall be treated as specified in Section 105.

107. Hydraulic concrete foundation shall be constructed in compliance with the requirements of Sections 28, 29, 30, 31, 32, 33, 34, 35, 36 and 37 of these specifications. Its depth or thickness shall be..... ....inches.

108. Broken stone foundation shall be..... .inches in thickness after completion. It shall be constructed in accordance with Section 40 of these specifications.[1]

109. When completed the upper surface of the foundation shall nowhere be more than two and one-half (2 1/2) inches nor less than one and three-fourths (1 3/4) inches below the pavement datum. No travel shall be permitted upon the foundation until the bituminous concrete shall have been laid.

110. Bituminous Concrete.—The bituminous concrete shall be composed of crushed stone, sand, pulverized stone, and asphaltic cement.

A typical composition for the bituminous concrete, to be as closely approximated as practicable, is as follows, the percentages being by weight:

[1] Where a new foundation is required broken stone or macadam is most frequently used for bituminous concrete pavements. Unless such foundations are constructed in the same way and with about the same care as is necessary for a macadam road it is liable to prove unsatisfactory. Under the very heavy wheel loads that may occasionally pass over the streets, imperfectly compacted broken stone is likely to shift sufficiently to start incipient ruts which will enlarge and in time necessitate expensive repairs. Such conditions are frequently seen on bituminous concrete pavements subjected to heavy travel. These pavements, like sheet asphalt pavements, require a foundation that will be absolutely unyielding under travel. For this reason a concrete foundation will generally be found more economical in the long run than a broken stone foundation. The increased first cost per square yard is not very great and this additional money will in most cases prove a good investment. At the usual prices of material and labor a square yard of 4 inch concrete should cost about 50 cents, while a properly constructed broken stone foundation 6 inches thick (which would not nearly equal in strength and rigidity 4 inches of concrete) would cost about 45 cents per square yard. Considering the much greater durability and lower cost of repairs of the pavement on the concrete foundation, this small additional cost is not worth consideration. While the specifications are made to cover the three kinds of foundation, it is assumed that the kind of foundation to be used will be decided in advance, and that the part of these specifications relating to the others kinds of foundation will, in actual use be omitted.

Pure bitumen in asphaltic cement	8.5%
Pulverized stone passing No. 200 sieve	8.5%
Sand passing No. 80 sieve	10.0%
Sand passing No. 40 sieve	23.0%
Sand and fine stone passing No. 10 sieve	15.0%
Crushed stone passing a screen having four meshes to the linear inch	25.0%
Crushed stone passing a screen having two meshes to the linear inch	10.0%
	100.0%

The crushed stone shall be trap-rock, granite or hard, sound, durable limestone. It shall be crushed to such sizes that all will pass through a screen with two meshes to the linear inch and shall be of such assorted sizes of fragments as will, when incorporated with the sand, pulverized stone, and bitumen, produce a mixture substantially conforming to the percentages of each named in the preceding paragraph.

The stone shall be freshly crushed, clean and free from clay, loam, organic matter and refuse of every kind.

The sand shall be silicious, and free from clay, loam and refuse of all kinds. The grains shall be of such sizes that approximately twenty-five per cent. (25%) of the whole will pass the number eighty (80) sieve, fifty-eight per cent. (58%) shall pass the No. 40 sieve and not more than seventeen per cent. (17%) will pass the number 10 sieve, when used in the order named. The pulverized stone shall conform to the requirements of Sect. 49. Portland Cement may be substituted for not more than twenty per cent. (20%) of the pulverized stone if the Engineer so directs, in which case the Portland Cement actually so used shall be paid for extra at the prevailing market price, to be agreed upon in advance. The asphaltic cement shall comply with the requirements of Sects. 43, 44, 45, 46, 47, and 50, except that it may have a somewhat higher penetration, as may be determined by the Engineer.[1]

[1] A bituminous cement composed largely of coal-tar pitch has heretofore been most used in pavements of this character. It is not denied that very good pavements have been, and can he built with this material, but the superiority of the asphaltic cement here specified is so great that it is true economy to use it. The difference in cost at prevailing prices of material will be ten to twelve cents per square yard. The greater durability and serviceability of the pavement made with the asphaltic cement will, particularly on streets of comparatively heavy travel, far more than justify this additional cost.

111. Mixing.—The materials composing the concrete shall all (except the pulverized stone and Portland cement) be uniformly heated to a temperature not exceeding three hundred and fifty degrees Fahrenheit (350° F.) and not below three hundred degrees Fahrenheit (300° F.), and while at such temperature shall be incorporated and mixed in a mechanical mixer. The stone, sand, and pulverized stone shall be placed in the mixer in the order named and well mixed together, after which the asphaltic cement shall be added and the mixing continued until each fragment is thoroughly coated with cement.

112. Laying on the Street.—The mixed concrete shall be taken to the street as soon as practicable after leaving the mixer. It shall be unloaded on the street, properly spread and truly graded with asphalt rakes to such a depth that after compression by rolling it will have a thickness of not less than two inches. The concrete when unloaded on the street shall be at a temperature not below two hundred and eighty degrees Fahrenheit (280° F.). In spreading and grading, all material must be moved from the pile into which it was unloaded. As soon as practicable after the concrete shall be graded, the surface shall be thoroughly rolled with a ten-ton asphalt roller and the rolling continued until the roller makes no further impression on the concrete surface. When completed the surface must conform closely to the pavement datum so that there will be no depressions or elevations exceeding one-fourth inch above or below the pavement datum.

HYDRAULIC CONCRETE ROADWAY PAVEMENT[1]

113. The sub-foundation for hydraulic concrete pavement shall be prepared as specified in Section 26.

[1] Hydraulic concrete pavement is to be recommended only for country roadways and for city streets of very moderate travel. While our experience with this kind of pavement is yet limited there is reason to believe from the nature of the material that it will not prove to be a satisfactory or economical pavement for streets of heavy travel. But in all cities and towns there are many residence streets where the travel is very light, and yet where a permanent pavement

114. The pavement shall be constructed in two courses called the bottom course and the top course, as hereinafter specified.[1]

115. Bottom Course.—The bottom course shall be four (4) inches in thickness[2] and shall be composed of the materials specified in Sects. 29, 30, and 31. The concrete shall be composed of one part Portland cement, three parts sand and six parts of broken stone, and shall be mixed and placed as specified in Sects. 35 and 36, but its top surface when properly compacted shall be parallel to and not less than two (2) nor more than two and one-half (2 1/2) inches below the pavement datum.

116. Top or Surface Course.—The top course shall be composed of the Portland cement specified in Sect. 29, the sand specified in Sect. 30 except that it shall be especially clean, and the grains shall be of such size that at least seventy-five per cent. (75%) of the mass will fail to pass a screen having thirty (30) meshes to the

is wanted and warranted. For these, it is believed that a properly constructed concrete pavement will prove very satisfactory and durable, and the low cost at which it can be constructed should make it very attractive to city officials and property owners. The author has advocated its use under such conditions for many years (see Engineering News, July 21st, 1904). Like other composite pavements its utility and durability will depend largely upon the good quality of the materials used and the skill and thoroughness with which the work is done.

The specifications here offered are the result of the observation and experience of the author, and it is believed that pavements laid in accordance with them will give very satisfactory results.

[1] A number of engineers advocate the construction of concrete pavement in one homogeneous course, and quite a number of pavements have been constructed in this way.

Like any other composite pavement, it is called upon to perform two functions; to safely sustain the weight of loads passing over it, and to resist wear and abrasion of its surface. A material and form of construction that meets the first requirement may not meet the second. Experience has proved that ordinary 1:3:6 concrete makes an entirely satisfactory foundation for any pavement, but it lacks the hardness and strength to successfully resist the surface abrasion of travel. To secure this quality a richer and harder concrete is called for, but it is unnecessary that the foundation should be equally hard. To construct the pavement in two courses as here specified would seem to be the logical way, especially as it decreases the total cost, and should make a more durable pavement.

[2] Some engineers advocate a greater total thickness of the pavement than is here specified (6 inches). Considering that this pavement should never be used on heavy traveled streets, a total thickness of concrete of six inches will have ample strength to carry the loads to which it will be subjected. If so, it is a useless waste of money to increase the thickness of the concrete.

linear inch, and shall be of superior quality for making concrete; and of crushed Trap Rock,[1] or of stone equally hard, strong and durable.

The trap rock shall be crushed to such sizes that all will pass through a screen having meshes one and one-fourth (1 1/4) inch square and that none will pass through a screen having meshes one-half (1/2) inch square,[2] and it shall be free from clay, refuse or other foreign substances.

117. The surface-course concrete shall be composed of one part Portland cement complying with Sect. 29, one and three quarters (1 3/4) parts of sand, and, generally, three and one-half (3 1/2) parts of crushed stone, but the ratio of crushed stone shall be such that in the completed concrete the volume of mortar in the compressed mass shall exceed by about fifteen per cent. (15%) the voids in the stone.[3] The cement and sand shall be thoroughly mixed together dry, enough clean water then added to make a rather wet mortar and the mixing continued until the materials are thoroughly incorporated into a homogeneous mass. The crushed stone shall then be added, and the mixing continued until every fragment of stone is completely covered with mortar. Sufficient water shall be added during the mixing, if necessary, to make a "wet" concrete, but not so wet that free water will flow from the mixed mass. In handling and adding the stone to the mortar care must be taken to prevent the stone segregating into masses of different sizes. The concrete for the top course shall be made

[1] The use of limestone for the top course (unless it is of very superior quality) is not advisable or economical unless the cost of trap rock is so high as to be prohibitive, which, considering its superior durability under the wear of travel, will not often be the case.

[2] It is advisable to remove the screenings from this surface mixture for two reasons: first, to secure greater uniformity of composition. If the screenings are allowed to remain in the aggregate, there is danger of segregation into patches of different sized aggregate and different ratios of materials, which it is very important to avoid, and second, the small fragments of stone are more likely to be crushed under the concentrated weight of wheels than the larger masses, and to thus start disintegration. Lack of uniformity in the composition and homogeniety in this surface course concrete is especially to be guarded against, otherwise the surface of the pavement will wear unevenly and depressions and ruts are likely to result.

[3] The ideal composition of this surface-course concrete is one where the stone forms the largest possible part of the mass consistent with sufficient mortar to fill the voids and thoroughly bind the fragments of stone together.

with special care and thorough work, the intention being to secure a superior quality of concrete.[1]

118. The concrete thus prepared shall be placed upon the bottom course before the latter has begun to set[2] and carefully graded so that when properly compacted its top surface will coincide with the pavement datum. The concrete will then be well rammed by rammers having a face of 6 by 6 inches and weighing not less than twenty (20) pounds after which the surface will be completed by rolling with a power roller of the asphalt type weighing not less than five (5) tons.[3] All these operations must be completed before any of the concrete in either course shall have begun to set. The surface shall not be plastered with neat mortar nor shall it be trowelled.

119. The completed surface must coincide with the pavement datum to the extent that a properly formed template when applied to the surface shall show no departure from the pavement datum exceeding three-sixteenths (3/16) inch.

120. After the laying of the pavement has been completed it shall be allowed to stand until the concrete of both courses shall be fully set, which period shall be not less than ten (10 days), or longer, if conditions make a longer time necessary, as the engineer may direct, of which he shall be the sole judge. During this period the concrete shall be kept in a moist condition throughout, by sprinkling with hose or otherwise. No travel shall be allowed upon the street until the engineer shall open it for public use. The concrete shall not be laid during rain storms or when the thermometer is below forty-five (45) degrees F., and in case there may be danger from frost the whole surface of the concrete shall be covered by straw or hay. Manure must not be used for this purpose.

121. Expansion Joints.[4]—An expansion joint along the curbing on each side of the street shall be provided in accordance with Sect. 101.

[1] The importance of securing high quality and great uniformity in the surface course cannot be urged too strongly.

[2] This requirement must be strictly enforced. Otherwise there will be danger that the two courses may not properly adhere to each other. It is the writer's experience that if this rule is observed there will be no danger of the two courses separating.

[3] The purpose of this rolling is mainly to evenly compress the mass and thus secure its uniform density. It also produces a truer surface than can usually be secured by ramming alone.

[4] Among engineers there is quite a wide difference of opinion as to the proper spacing of expansion joints, and, in fact, as to the necessity or advisability of providing them at all. It has been suggested that it might be better to omit

Expansion joints shall also be provided and constructed as follows: Wherever the width of the pavement exceeds twenty (20) feet between curbs there shall be a expansion joint along the longitudinal center of the street; expansion joints shall also be made, at right angles to the street and extending continuously from curb to curb, at distances apart not exceeding twenty (20) feet. These expansion joints in the body of the pavement shall be made by cutting entirely through both courses of concrete along a straight line, using a special straight-edged cutter not more than three-sixteenths (3/16) inch thick, when the concrete is laid in hot weather and not more than three-eighths (3/8) inch thick if the concrete is laid when the thermometer is below sixty (60) degrees F. The cutting of the expansion joints shall be carefully and skillfully done, and after each joint is cut a special T-shaped smoother, the stem of which is one inch deep and of the same thickness as the cutter shall be worked back and forth in the joint until the edge of the concrete adjoining the joint shall be well and smoothly compacted. The smoother shall be so formed as to round off the corners of the concrete to a circular form having a radius of one-fourth (1/4) inch. All these operations shall be completed before the concrete has begun to set. After the concrete has set and before the street is opened to travel all expansion joints shall be poured full of bituminous cement, as specified in Section 90.[1]

122. Bituminous Coating.[2]—After the concrete shall have become fully set as determined by the engineer and before the street is

them entirely, allowing the pavement to form its own expansion joints by cracking along lines where natural forces dictate. Such cracks by their irregularity give a bad appearance to the surface, but observation seems to indicate that the edges of these natural joints wear as well as those made by expansion joints. Further observation and experience is needed in the matter. In most concrete it is known that some contraction takes place during the setting of the cement, regardless of temperature changes, and cracking is probably due as much to this permanent contraction as to that caused by low temperature. The coefficient of expansion of concrete by heat is variable but so small that expansion joints 1/8 inch wide every fifty feet along the street should provide for temperature changes.

[1] If the expansion joints are not thus filled with bituminous cement they will become filled and packed with incompressible stone, sand, etc., that will not permit expansion.

[2] The practical value of oiling concrete pavements has not yet been determined by sufficient experience. There is reason, however, to believe that the slight coating of bitumen will materially preserve the surface from abrasion and that its benefit will thus be greater than its cost. It will also tend to prevent the very slight dust that might otherwise exist on the pavement.

opened to travel the whole surface of the pavement shall be covered by a finishing coat of bituminous road oil as hereinafter specified.

The road oil shall be prepared from native asphalt or from a crude oil having an asphaltic base. Not less than 95 per cent. of the oil shall be soluble in cold carbon disulphide, and it shall contain not less than thirty (30) per cent. of solid asphalt, nor more than ten per cent. of fixed carbon. It shall be of such consistency as to flow freely at a temperature of seventy-five degrees (75°) F. The oil shall not be applied except when the road surface is perfectly dry and when the temperature of the air is not below 60° F.

The oil shall be evenly distributed over the whole surface of the street at the rate of one-half (1/2) gallon of oil per square yard of surface, and well worked over the surface with squeegees or other suitable devices.

Not less than twenty-four hours after the application of the oil the surface of the pavement shall be evenly covered to a depth of one-fourth inch with clean, dry stone screenings or coarse sand, after which the street may be opened to travel.

GENERAL SPECIFICATIONS FOR EXPERIMENTAL OR UNTRIED PAVEMENTS[1]

123. Contractors or promoters submitting proposals for the construction of new, experimental, or special street pavements, the merits of which have not been established by experience in the city of..... ...., must submit with their proposal a full and complete set of specifications for the construction of the pavement. If contract shall be awarded under said proposal, said specifications will be made a part of the contract entered into. The Engineer will enforce compliance with these specifications, as the construction work proceeds, without assuming or incurring any responsibility for the character, quality, serviceability or durability of the resulting pavement. But the Contractor shall be subject to and shall comply with the requirements and stipulations of Sects. 1 to 25, inclusive, of these specifications.

124. Special Guaranty.[2]—Inasmuch as the pavement to be con-

[1] In this class of pavements the contractor or promoter may properly be required to assume responsibility for the character and utility of the work produced, and the municipal authorities should assume no part of such responsibility.

[2] Upon the general subject of time guarantees of municipal work, see Chapter XI, "Municipal Public Works," by the author.

structed under the special specifications submitted by the Contractor is more or less of an experimental character, having not been heretofore used in the city of .....to an extent sufficient to establish its value, the Contractor shall be held wholly responsible for the utility, serviceability and durability of the pavement so constructed; and he shall enter into a guaranty to the effect as follows:

That the pavement will fulfill all the usual and legitimate requirements of a satisfactory roadway pavement upon the street upon which it is to be laid.

That the pavement will successfully serve and endure the travel to which the street may be subjected for a period of ..... years next following the date of the certificate of its completion and acceptance, and shall be in good condition at the end of that period, ordinary and reasonable wear and tear, and accidental or other injuries not due to defects in the pavement itself, excepted.

That the Contractor will, at his own cost, keep the said pavement in satisfactory repair during said period of..... years, and will leave it in a condition of satisfactory repair at the end of that period.

That the Engineer, or his successor or successors in office, shall be the sole and final judge as to whether the conditions of this guaranty shall be, or shall have been complied with.

That in case the pavement shall not, in the judgment of the Engineer, fulfill the terms and conditions of this guaranty at any time during said period of.....years, or upon its expiration; or in case the Contractor shall fail to make all or any of the repairs that may in the judgment of the Engineer be or become necessary during said period of ....years, within a reasonable period to be determined by the Engineer, but not to be less than twenty (20) days after notice to make such repairs has been given him by the Engineer, he (the Engineer) may proceed to make or to have made such repairs, or to repave the street, in any manner that he may deem necessary or advisable, and to charge the cost of such repairs or repavement to the Contractor, provided, that the sum or sums so charged against the Contractor shall not, in the aggregate, be more than the amount paid to the Contractor for the construction of the pavement.

125. Bond.—The Contractor shall give bond with sureties satisfactory to the Engineer in a sum not less than the estimated cost of the pavement at the contract prices, the term of the bond to extend

over the entire period of ..... .years, for which the pavement is guaranteed.

126. During the said period of..... ...years the Contractor shall, upon being notified by the Engineer so to do, make any repairs to the pavement that may become necessary by reason of cutting into it for the purpose of constructing or repairing pipes, conduits or other underground structures, or street railroad tracks, or by reason of accidental or unusual causes, or of any causes other than those due, in the opinion of the Engineer, to the failure of the pavement to meet and fulfill the terms of the guaranty stipulated in Section 124. And for making such repairs the Contractor shall be paid the price of ....per square yard for the repairs actually so made. Repairs so made shall be subject to the terms of the guaranty, stipulated in Section 124, until the expiration of the said term of..... . .years after the date of the original certificate of completion and acceptance. In case the Contractor shall neglect or fail to make such repairs within a period of twenty (20) days after he shall have received notice to do so, the Engineer may proceed to make or to have made such repairs, and he shall charge to and collect from the Contractor the cost of the repairs so made.

HYDRAULIC CONCRETE COMBINED CURB AND GUTTER[1]

127. Hydraulic concrete combined curb and gutter shall be constructed in accordance with general plan No. .....attached to and made a part of these specifications, but the rise from the gutter to the top of the curb may be varied so as to facilitate drainage.[2]

[1] Concrete combined curb and gutter is suitable for use on the great majority of residence streets, and others where the travel is not excessive, or where it will not be subjected to specially severe use, as on business streets where heavy vehicles are likely to be often backed against the curb. If properly constructed it will have sufficient hardness and strength to withstand all ordinary usage; it makes a better appearance, particularly on residence streets, than any other kind of curbing, is durable, and is usually less expensive than any other suitable, equally durable and equally well-finished curbing of natural stone, since the gutter displaces an equal area of pavement.

[2] The sketch here presented conforms pretty closely to usual practice except in the width of the gutter. It is not uncommon to make the gutter from two to three feet wide. This is not necessary or desirable. A width of 15 to 18

128. Excavation.—All excavation required for the curb and gutter shall be completed and trimmed to the proper lines as shown by the drawing. The drainage trench under the curb and gutter shown on the drawing shall have the top width and general form shown in the drawing but its depth may be varied to secure proper drainage, as the engineer may direct, provided that its depth below the base of the concrete shall not be less than nine inches nor more than two feet.

129. Broken Stone Drainage.[1]—After the excavation shall have been completed the trench shall be filled up to the level of the base of the concrete with sound, durable broken stone, or coarse gravel, from which the small fragments shall have been removed by screening over a wire screen having openings not less than one inch square. The stone or gravel shall be thoroughly tamped in the trench in layers not more than six (6) inches thick by the use of rammers weighing not less than thirty (30) pounds and having a face area not exceeding thirty-six (36) square inches, and its completed top surface shall conform truly to the designed base of the concrete. These drains shall be connected at suitable intervals with sewers, drains or other outlets to keep them free from standing water. The trench filling shall be completed at least twenty-five feet in advance of placing the forms for the concrete.

130. Concrete.[2]—The concrete shall be made of one (1) part

inches forms a sufficient gutter to carry away all drainage except during very heavy rainfalls. Where the gutter projects out into the street sufficiently far to be exposed to large numbers of heavily loaded wheels the outer corner is likely to become broken off or unduly abraded.

[1] Curbing of all kinds is more likely to be injured by freezing and the heaving of frost under and around it than from any other cause. Good drainage is the best protection against such injury. It is important that these drains shall be connected with sewers, drains or other outlets, so that water will not stand in them.

[2] The most notable departure of these specifications from usual practice is the use of a solid body of rich, homogeneous concrete for the whole section of the structure, thus avoiding the use of two courses and qualities of concrete—the core concrete and the facing. The most common cause of failure of concrete curbs and gutters is the separation, more or less, of the facing from the core concrete. Without doubt this can be prevented by the use of proper materials, careful work, and the strict observance of the rule that the facing course must be applied before the core concrete has begun to set. But it is difficult to always secure these favorable conditions. Computation will show that the difference in cost of materials, between the usual two-course construction and a single body of rich concrete throughout, is not very great, while the saving in cost of labor is so considerable as to make the actual difference in cost of the two types

Portland cement, one and three-fourths (1 3/4) parts of sand and three (3) parts of crushed stone or clean gravel. The Portland cement shall comply in all respects with the requirements of Section 29 of these specifications.

The sand shall be clean, sharp silicious sand made up of grains of such size that not more than fifteen per cent. (15%) will pass a number thirty (30) sieve. It shall not contain more than five per cent. (5%) of clay or loam nor more than two per cent. (2%) of organic matter or other refuse. The stone shall be sound, hard, durable, and freshly broken, free from clay, loam, organic matter, or other impurities. Trap rock or granite will be preferred, but limestone, if hard and sound, may be used with the approval of the engineer. Only those fragments of the crushed stone that pass a screen with openings three-fourths inch square and those that are held on a screen with openings one-fourth inch square shall be used in the concrete.

131. Mixing and Placing Concrete.—The concrete shall be mixed in accordance with Section 35 of these specifications. Very thorough mixing will be required.

The mixed concrete shall be handled so as to prevent as far as practicable any separation or segregation of the stone and mortar. When in place it shall be compacted by tamping and where placed against forms, forking or other effective means must be used to bring mortar to the surface and to secure complete contact between mortar and forms, so as to leave a solid, homogeneous and unbroken surface when the forms are removed. Where the concrete may not be laid against forms, all exposed surfaces must be troweled to a true surface conforming accurately to the lines shown by the plans, templates and straight-edges being used where necessary.

132. Weather.—Concrete in combined curb and gutter shall not be laid in freezing weather nor shall frozen materials be used in the work. Completed work must be securely protected from frost for at least seven days after it is laid. Any concrete curb and gutter that may become frozen within that period shall be wholly removed and replaced with new work.

133. Expansion Joints.—The combined curb and gutter shall be divided into blocks or panels not more than twelve feet long, by clear, open expansion joints perpendicular to the face of the curb,

very small. There can be no doubt that the simpler construction and the consequent greater certainty of securing a durable and satisfactory job is greatly in favor of the construction here recommended.

extending entirely and continuously through the whole mass of the concrete. These expansion joints shall be three-eighths inches wide and may be formed either by cutting through the completed curb and gutter with a suitable tool, or by the use of iron forms or partitions, but in either case the corners at the ends of the blocks must be made solid and dense and troweled with a suitable tool.

134. Circular Corners.—At the intersections of streets, circular corners, having a radius equal, generally, to one-fifth of the width of the roadway of the narrower street, shall be constructed of the same dimensions and quality as on the body of the street, and the curb and gutter will be extended along the line of the cross street back to the front lot-lines. Properly curved circular curb and gutter shall also be constructed at all angles exceeding five degrees in the line of the curbing.

135. Corner Protection.—Galvanized steel corner protectors or nose-pieces shall be used to protect the upper and outer corner of the curb at all circular corners and angles in the street. This steel protection may be of any pattern or section procurable in the market and approved by the engineer. It shall be firmly anchored and secured into the concrete.

136. Finishing.—After the forms have been removed and before the concrete has set up too hard to be affected by the brush, the face and top of the curb shall be lightly scrubbed by a suitable wire brush so as to completely remove any glazed surface and to produce a surface of uniform texture and appearance. Dry cement or neat cement mortar shall not be used for dressing up exposed surfaces.[1]

137. Forms.—The forms used may be of dressed lumber or of metal as the contractor may prefer. But they shall have sufficient strength and rigidity to hold the concrete firmly in place, and to preserve the correct dimensions, alignment and levels of the curb and gutter.

138. Protection.—The completed curb and gutter shall be protected from fracture, deformation or spalling until the concrete has fully set. The concrete must be kept moist for at least five days

[1] The appearance of "hair cracks" on the surface of rich concrete, finished by troweling, and the blotched appearance of the surface of concrete curbing, are usually caused by improper finishing. The glazed surface produced by troweling, particularly where pure, dry cement or neat mortar is applied is almost sure to develop hair cracks, and the varying texture of the surface is likely to absorb water unevenly and thus produce, in time, the unevenly colored or blotched surface so often seen.

after it has been laid. Any part of the curb and gutter that shall have become injured before it is accepted or the street is opened for travel shall be taken up and replaced by the contractor.

139. Payment.—Concrete combined curb and gutter will be paid for by the linear foot in place, the measurement to be made along the upper and outer corner of the curb. The price per linear foot named in the contract will cover all the excavation or grading required and all the materials and labor, including all necessary forms, for constructing the curb and gutter complete. But the crushed stone used for drainage will be paid for by the cubic yard measured in place, and steel corner protection will be paid for by the linear foot in place, at the prices named in the contract.

HYDRAULIC CONCRETE SIDEWALKS

Note.—These specifications conform to the common practice of laying the sidewalk in two courses.

In the author's judgment this is neither necessary nor desirable. He believes that it would be better and somewhat cheaper to use a single course of concrete four inches in thickness. He suggests for this concrete the ratios of one cement, two sand, and three and one-half stone, the latter to be crushed to pass a screen with five-eighths inch square openings.

Tamping will bring a sufficient quantity of mortar to the surface to permit of satisfactory finishing. While the materials for such a single course of four inch concrete would cost somewhat more, the saving in cost of labor would, at usual prices of material and labor, make the single-course construction somewhat cheaper, while the solid four inches of richer concrete would make the walk much stronger. In fact, a single course of such concrete three inches thick would be sufficient in a great majority of cases. While the surface might not have the glazed appearance common in the two-course work it would be really better for use—a polished and slippery surface on sidewalks is not desirable.

SPECIFICATIONS [1]

140. The hydraulic concrete sidewalk shall be .... feet in width and its outer edge shall be..... . .....feet from

[1] The utility and durability of hydraulic concrete sidewalks depends largely on the quality of materials and workmanship employed in the work. Too frequently, specifications for this work are not sufficiently full, or not prepared with the requisite care, or the work is not properly supervised or inspected while in progress. The aggregate importance and cost of this sidewalk work in our cities warrants more care and attention than it generally receives.

the outer face of the street curbing. It shall be constructed with two courses of Portland cement concrete as hereinafter specified.

141. Excavation and Grading.—The ground to be occupied by the sidewalk shall be excavated or filled to a sub-grade which after being compacted shall be.. .....inches[1] below the finished surface of the sidewalk. The sub-grade shall be neatly dressed to a plane surface sloping downward toward the street one-fourth inch in one foot horizontal, and to such longitudinal gradients as the engineer may prescribe. The completed sub-grade shall project four (4) inches in excavation and eighteen (18) inches in embankment on each side beyond the edges of the completed sidewalk. After the grading is completed the surface shall be compacted by rolling or ramming.

142. Drainage Course.—Upon the sub-grade prepared as specified in Section 141 a drainage course composed of broken stone, gravel or boiler-plant cinders,.....inches[2] in thickness shall be laid. Broken stone for this purpose may be of any durable stone crushed to such size that all will pass through a screen with two inch openings. Crusher-run material may be used unless it contains an excessive quantity of fine material. Gravel for the purpose may be any sound durable gravel all of which will pass through a two inch screen and be retained upon a one-fourth (1/4) inch screen. If cinders are used they must be good boiler-plant cinders from which the ashes have been screened out. The cinders must be thoroughly drenched with water at least one week before they are placed in the sidewalk.[3]

[1] Determined by the thickness of the drainage course adopted.

[2] It is customary in many cities to require that the drainage course under the concrete shall have a depth of twelve or more inches. This deep-drainage is designed to prevent the heaving of the sidewalk by freezing. Experience seems to prove that this is not necessary, particularly if tile drains are provided to carry off the water from the drainage course, as specified. Comparatively dry material, even earth, does not heave with freezing; on the other hand, if the material and the trench in which it is placed is wholly or partly filled with water, heaving is liable to occur in severe freezing weather, whatever the depth of the drainage course. Experience has proven, however, that four inches of drainage material is sufficient if the water is drained out of it, while if allowed to stand saturated with water, deeper drainage will give little if any better results. Where the soil is sandy or the natural drainage is otherwise good, no drainage course is necessary.

[3] Except in the matter of low first cost cinders are not desirable for the drainage course. In time, this material is likely to slack, or decompose, and shrink in volume more or less and to allow the sidewalk to settle. The hollow sound one often notices when walking over a sidewalk and the cracks that frequently appear,

143. This drainage material shall be placed on the sub-grade and properly graded. After grading it shall be thoroughly compacted by ramming or rolling, and its surface shall be brought to a plane parallel to and. ..... .inches below the designed surface of the sidewalk, after which the surface inequalities may be leveled up with screenings or small gravel.

The bottom of the drainage course shall be connected with the street drains or sewer inlets by three-inch hard drain pipe at such points, not nore than three hundred feet apart, as will drain all standing water out of the drainage course.

144. Concrete, Bottom Course.—The bottom course of concrete ....[1] inches in depth, shall be constructed and placed in accordance with Sections, 28, 29, 30, 31, 32, 33, 34, 35 and 36 of these general specifications, except that the maximum size of the crushed stone shall not exceed one-half the thickness of the bottom course of concrete and the concrete shall be uniformly composed of one part Portland cement, three parts sand and six parts of crushed stone. Its upper surface shall be brought to a plane parallel to and one inch below the designed sidewalk surface.

145. Surface or Finishing Course.—The surface or finishing course shall be of concrete, one inch thick, composed of one part Portland cement, one and one-half parts sand and two and one-half parts of hard, durable stone, crushed to such sizes that all will pass through a screen having openings one-half (1/2) inch square and none will pass through a screen having openings one-eighth (1/8) inch square.[2] This concrete shall be made as specified in Sections 28, 29, 30, 31, 32, 33, 34, 35 and 36 except in the particulars named in the preceding paragraph. Care must be taken to make the mixing very thorough. The quantity of water used in this concrete shall be just sufficient to make a moderately wet mixture, and care shall be taken

are usually caused by the irregular settlement of the drainage course. The object of wetting down the cinders several days before they are used is to cause as much as possible of this slacking to take place before the cinders are used in the drainage course.

[1] There is a good deal of diversity of practice in the thickness of the concrete to be used. For all ordinary sidewalks three inches of bottom course and one inch of surface course are ample, and in many cases the thickness of the surface course has been reduced to one-half inch with satisfactory results. Three-fourths inch of surface course, if fairly uniform in thickness and of good quality, will generally be ample for ordinary sidewalks.

[2] It is customary to make the surface-course concrete much richer than this, but it is not necessary if the materials are good and the work well done.

to make the different batches as nearly as practicable of the same consistency.

The surface concrete shall be spread over the bottom-course concrete before the latter has begun to set,[1] properly graded, well compacted by ramming, and its upper surface brought to the true designed plane and surface of the sidewalk by the use of straight edges and troweling,[2] after which the surface shall be lightly gone over with a wire broom or brush to slightly roughen the surface. The finished plane of the sidewalk shall have a transverse downward slope toward the street of one-fourth (1/4) inch to one foot of horizontal width. At no place shall the thickness of the surface course be less than three-fourths of one inch. The outer top corners of the sidewalk shall be rounded off with a suitable tool to a radius of three-fourths (3/4) inch.

146. Forms.—Substantial and suitable forms of wood or iron shall be furnished and used by the contractor to support the concrete until it is hard set, when they shall be removed at his expense.

147. Expansion Joints.—After the laying of both courses of concrete is completed expansion joints at right angles to the sidewalk, and not more than four (4) feet apart shall be constructed in the sidewalk in the following manner: the joint will be located by a line on the surface of the sidewalk and a straight-edged cutting tool one-fourth (1/4) inch thick will be used to cut entirely through both courses of concrete, accurately along the line marked out, entirely across the sidewalk, after which a T-shaped trowel or tool shall be used to smooth and compact the cut surfaces for a depth of one inch, and to round off the corners of the sidewalk blocks to a radius of one-fourth (1/4) inch.[3]

Where the ends of the sidewalk abut against the curbing a clear

[1] This requirement is very important and should be strictly enforced, otherwise there is danger that by the action of water, frost, and time, the two courses may separate and the surface course break up—a condition not infrequently observed.

[2] The troweling not only helps to secure a true surface, but tends to produce a dense surface on the concrete; but it is not desirable that this surface shall be smooth and glassy, hence the slight roughening of the surface with a wire brush.

[3] Care must be taken to make and leave these expansion joints open to their full width entirely through the concrete. The practice of forming these expansion joints by partitions of iron plate, against which the blocks of sidewalk are built is not advised, for the reason that they are likely to prevent the thorough compression of the concrete surface against or near the plates.

expansion joint one and one-fourth (1 1/4) inches wide shall be left between the sidewalk and the curb.

148. After the concrete laying is completed it shall be protected from use or injury until the concrete is set hard enough to withstand travel, and it shall be kept continuously damp for at least five days after the concrete is laid.

149. **Weather.**—Concrete in sidewalks shall not be laid in freezing weather nor shall frozen materials be used in the work. Completed work must be securely protected from frost for at least seven days after the concrete is laid. Any concrete sidewalk that shall become frozen within that period of time shall be wholly taken up and replaced with new work, at the expense of the contractor.

150. **Regrading.**—Directly after the concrete is completed, the forms removed, and the work inspected by the engineer, the space between the outer edge of the sidewalk and the street curb shall be excavated or filled up and dressed to a plane one inch below the top of the sidewalk and the top of the street curb; and the space on the inner side of the sidewalk shall be graded to a plane one inch below and parallel to the surface of the sidewalk for a distance of two feet back from the edge of the sidewalk and completed with a slope of one and one-half to one to the natural surface of the ground. Where this regrading requires filling up the filling material, for a depth of four inches from the surface, shall be good, rich surface soil.

151. Should any defects due to faulty material or workmanship develop in the sidewalk within one year after the completion of the same the contractor shall repair or reconstruct all such defective places at his expense, doing the work in accordance with these specifications.

152. **Measurement and Payment.**—Concrete sidewalk will be measured and paid for by the square foot of completed sidewalk surface, and the unit price per square foot shall cover the entire cost of the work, including grading, drainage work, all material and labor, forms, and the regrading or dressing up after the completion of the concrete work; except that the drain pipe used will be paid for per linear foot at the price named in the contract which price shall cover the cost of furnishing and putting the pipe in place complete.

PART II

INSTRUCTIONS TO INSPECTORS ON STREET PAVING WORK

INTRODUCTORY NOTE

Any general code of instructions for inspectors on street paving work must necessarily be little more than tentative or suggestive, as applied to any one city.

That here presented is intended for use in connection with the specifications in Part I of this book. Different specifications might make necessary many changes in the instructions that follow. The local or special conditions in any city might also make them inapplicable without material modifications and additions.

The author believes that in every city where considerable street pavement work is prosecuted and a number of inspectors employed on such work, some such code of instructions to inspectors should be formulated and used. Even where the inspectors are of high character and fully competent, the adoption of a system of rules and regulations relating to their work will tend to unify procedure, prevent misunderstandings and promote good discipline.

The preparation of such a code of instructions requires no little time and thought, especially where there are no precedents to suggest what is needed, or to be used as rough patterns. It is with the hope that the code here presented may be found useful in this way, even though it may be not appropriate for adoption in any given city, that it is offered to municipal engineers.

GENERAL REMARKS ABOUT INSPECTION AND INSPECTORS

The necessity of having competent and honest inspectors upon any public work during its construction need not be here argued. It is generally understood and recongized in the case of work carried out by contract. Where the contractor is incompetent, careless or unreliable, inspection is absolutely necessary if good work is to be secured. Even where the contractor thoroughly understands his business and intends to faithfully comply with the specifications and to do all his work in a proper manner, the inspector cannot safely be dispensed with. The contractor cannot at all times be on the work; whatever may be his intention and instructions, foremen and laborers cannot be depended upon to exercise the proper

care and judgment, even where they have no inclination, motive or interest to do otherwise, which is not always the case. It seems to be deeply and almost irradicably fixed in the mind of the average foreman on municipal work that he is expected to show his ability and skill by evading or circumventing the strict requirements of the specifications and the watchfulness of the municipal agents, whatever his employer may *say* to the contrary. Even when fairly careful, honest and conscientious he may need friendly oversight. He is naturally and properly anxious to save all the money he can for his employer, whether from a desire to loyally serve that employer's interest, or to enhance his reputation for doing work cheaply. He may not appreciate the importance of minor requirements of the specifications and may believe they can be ignored without real detriment to the utility of the completed work. Like other men he may sometimes be careless or forgetful, however good his intentions.

These human qualities are not confined to foremen on *contract* work. They are liable if not likely to be found in the foremen on work done for the municipality by the direct, or day's work system. They may be encouraged by the impression or belief that they will not be held by the municipal authorities to as strict an observance or accountability as they would be if the work were being done by a contractor—which is too often true. The absence of some of the motives of foremen employed by contractors is, therefore, not a sufficient reason for dispensing with inspectors on work done by the city direct.

It should be trite to say that inspectors should be chosen with some regard to their qualifications for the work they are expected to do. One cannot, of course, expect to secure experts for such positions at the rate of compensation usually paid; but it is reasonable to require that an appointee to such positions shall possess the following qualifications:

That he shall be honest, trustworthy and loyal.

That he shall be a man of at least average intelligence and common sense.

That he shall have some practical knowledge of or experience in the work he is employed to inspect.

That he shall be a man of good personal habits.

That he shall be habitually punctual, industrious, and alert, and shall possess a fair share of that quality commonly called "backbone."

It will not, I am sure, be denied that a very large number of the

inspectors found upon municipal public work fall short in one or more of these qualifications.

Inspectors who habitually expect or accept compensation or gratuities from the contractor violate the first requirement, and their number is astonishingly large. These are useless, or worse than useless, to the municipality. There are not a few contractors who will take advantage of the presence on the work of such inspectors to do things that they would not do if thrown wholly on their own honor and responsibility. Contractors can hardly be blamed for expecting some compensation for the money thus exacted or accepted by the inspector from them.

The requirement that the appointee shall have some practical knowledge of and experience in the work he is expected to do, while often disregarded, is of real importance. Good workmanship embraces many small details that are essential, and inferable from the specifications, but cannot be stated at length therein, and the inspector should have a good working knowledge of these.

Unfortunately, large numbers of inspectors are employed for personal or political reasons, or because more competent men are not available. They know little or nothing from practical knowledge and experience about the work they are assigned to inspect. Efficient service cannot be expected from such, even if they possess the other necessary qualifications. The obvious remedy, where a sufficient number of qualified inspectors cannot be obtained at call, would be to train up a permanent force by having the promising tyros serve a sufficient apprenticeship under older and more experienced inspectors; but this is seldom done.

Inspectors, whether appointed by the engineer in charge or not, should be absolutely under his control, including the power of dismissal without unnecessary formalities. Where they are under civil service regulations and can be dismissed only upon charges and after a hearing before some third person, the obstacles in the way of promptly getting rid of an incompetent or unfaithful inspector are often so great as to be discouraging if not deterrent. He may be clearly below a reasonable standard of honesty or efficiency but it may be very difficult to formulate distinct charges and support them with positive evidence. Thus, one may be morally certain that an inspector is accepting gratuities from a contractor, but unable to prove it by legal evidence. If in such cases the judgment and integrity of the responsible engineer cannot be trusted, he is not fit, himself, for the position he occupies.

The question of how much authority and power shall be given to the inspector is always a troublesome one. If he be too much limited or restricted, he cannot properly discharge his duties or command the necessary respect from the contractor and his employees; if he be given too much authority and is disposed to be arbitrary or unreasonable, the contractor may be unjustly treated. So far as the definite requirements of the specifications are concerned there can usually be no room for going astray, but in the numberless little details not specifically covered in the specifications, or where their language and intent is not clear, differences and disputes may result which require a degree of knowledge and judgment that the inspector may not possess, and where his decisions might be against the interests of the municipality or unjust to the contractor. In such cases the matter should always be referred to the engineer or his assistant.

Where inspectors are employed upon work done directly by the municipality the relation between them and the superintendent or foreman should be clearly defined and understood. Briefly stated, this relation should be the same as that between the inspector and the contractor on contract work.

INSTRUCTIONS FOR THE GUIDANCE OF INSPECTORS ON STREET PAVING AND INCIDENTAL WORK

GENERAL

1. The chief duty of the inspector is to see that the work to which he is assigned shall be carried out in full and strict accordance with the plans and specifications therefor, and with such additional instructions as may from time to time be given by the engineer.

2. These instructions are intended to supplement but in no case to take the place of the specifications for the work, which must be fully and strictly complied with, unless they are changed or modified by the engineer.

3. Wherever the words "*the engineer*" are used in these instructions they refer to the chief engineer in charge of the work for the municipality, or his authorized deputies or agents.

Wherever the words "*the contractor*" are used they refer to the person, or firm, or corporation under contract to perform the work to which you are assigned, or his agents or employees engaged upon the work.

4. You will report to and be under the exclusive direction and control of the engineer.

5. Upon being assigned to any work you will obtain copies of the plans and specifications under which it is to be done, and will carefully read and acquaint yourself with all their provisions and requirements. If any part of these plans and specifications are not clearly understood by you, you will ask the engineer for explanations and instructions, and will be governed thereby. Failure to understand or to be familiar with the plans and specifications will in no case be accepted as an excuse for not complying with and enforcing them.

You will also obtain, study and familiarize yourself with all the blank forms, reports, etc., that are to be used by you on the work, so that they may be correctly utilized; you will also obtain a proper supply of such apparatus, tools, stationery, etc., as you will need upon the work.

6. In inspecting any work done under contract you are to assume that the contractor is bound to carry out in good faith the plans and specifications attached to his contract, and that he may be, and must be, held to a strict compliance with them unless you receive instructions to the contrary from the engineer. You will be held responsible for the enforcement of these plans and specifications so far as they relate to the doing of the work.

7. In case the contractor or his agents shall neglect or refuse to comply with the plans and specifications or to perform the work in a proper manner, or in accordance with the instructions of the engineer, you will direct him to suspend the particular work in fault and will report all the facts promptly to the engineer and await his instructions, which, when received, you will proceed to enforce.

8. You will be expected to be upon the work at all times when work is in progress, whether during ordinary working or office hours, or not. But in case the contractor shall work continuous day and night forces, or otherwise so conduct the work as to require the presence of an inspector for unusual or unreasonable hours of service, you will notify the engineer and ask instructions or assistance. If for any reason you are to be unable to be present whenever work is in progress you will promptly notify the engineer in time to enable him to supply a substitute.

9. All reports and records required of you by the engineer must be promptly made up and forwarded to him at the time and in the manner he may direct. You will promptly acknowledge in person

or writing any instructions received from the engineer and in case such instructions are not clearly understood by you, you will ask for explanation or advice.

You will keep a notebook or diary in which all occurrences or matters of interest relating to the work will be recorded each day, which book will be delivered to the engineer on the completion of the work, or whenever your connection therewith may end. All diaries, notebooks and records kept on the work are the property of the city.

10. While your first duty is to see that the work is done in accordance with the plans and specifications, you will, so far as consistent with this duty, be considerate of the interests of the contractor and facilitate his work as much as practicable. Materials should be inspected promptly upon delivery and in such a manner as not to delay or discommode the contractor more than is necessary. Errors, defects or delinquencies in the work should be detected and called attention to promptly, so as to avoid tearing up and re-construction as far as practicable.

11. Orders and instructions should be given to the contractor or his foremen or representatives on the work and not to the laborers, unless in urgent cases.

12. You shall not at any time, before, during, or after the completion of the work, ask or accept from the contractor or any of his agents or employees, or from any other person whom you may have reason to believe is acting for the contractor, any money, gifts, gratuities or other considerations of value, whether as compensation for services rendered him or otherwise. The penalty for violation of this rule will be dismissal from the service followed by such legal prosecution as the engineer may direct. This rule does not apply to the ordinary small courtesies common between gentlemen associated in business.

13. It is a condition of your employment that your services shall be loyal to the interests of the municipality, efficient, and satisfactory to the engineer, and that whenever in his opinion your service falls short of this standard he may dismiss you at any time, without previous notice.

STREET PAVING WORK

14. **Sub-foundation.**—The usual procedure in preparing the sub-foundation for a pavement is:

The removal of the old pavement if one exists on the street.

The setting of new or the resetting of the old curbing. (If concrete combined curb and gutter is used it is not constructed until after the rough grading is done.)

The rough grading of the street.

The fine grading of the street.

In this work the main things for the inspector to look after are the following:

If an old pavement is to be taken up and any part of it is to be reserved for use by the city, see that the material is not injured in handling and is disposed of as the specifications or the instructions of the engineer require.

15. Curbing.—New curb stone should be inspected as soon as practicable after it is delivered on the street so that the contractor may have time to replace any that may be rejected. Rejected stones should be plainly marked on their tops with red paint, and the contractor required to remove them from the street. Stones that are defective in dressing should be given some distinctive mark and the attention of the contractor called to them so that the necessary redressing may be done well in advance of the setting, and reinspected.

If the old curb stone is to be redressed and reset, it should be inspected as soon as possible after it is taken out and all stones that are not suitable for re-use rejected and removed from the work. The redressing of the stones should be looked after carefully. The tendency in this work is toward the use of old stones that do not, or cannot be made to comply with the specifications, and toward laxity in the dressing.

Setting Curbing.—In the setting of curbing the points to be looked after are:

To see that the trenches are excavated to the full dimensions so as to provide space for the use of the full quantity required of concrete, gravel or broken stone in which the curb is to be embedded.

To see that the stones are set to true grade and alignment.

That the concrete, gravel or crushed stone used is of the proper quality, the proper quantity used, and that it is placed and compacted so as to fill the spaces designated under and around the stone. The tendency of the workmen is to treat these details as unimportant and to slight the work.

After the curbing is set any spaces between it and the edge of the sidewalk are to be cleaned out, filled and trimmed with Portland cement mortar.

16. Rough Grading.—If plows and scrapers are used in the rough grading. see that they are not allowed to penetrate or to disturb the natural soil below the true grade, and to prevent this it is better to require that the plowing and scraping shall not approach nearer than one or two inches to the true grade.

If embankment or filling is necessary, the filling material must be deposited in regular layers not more than six inches deep and each layer must be well compacted by rolling or ramming before the next layer is applied.

17. Fine Grading.—The fine grading (with pick or mattock and shovel), to bring the sub-grade to the true grade and contour required, should be done with reasonable accuracy and care. Allowance must be made for compression under the roller, so that when completed the surface shall not vary more than half an inch below nor more than a quarter of an inch above the true grade, in order that room for the full thickness of concrete foundation may be provided, and no more. Humps, depressions and irregularities of the surface are to be avoided. The fine grading will be completed by thoroughly rolling or tamping the surface to make the soil firm and dense. On some soft or wet, clayey soils, excessive rolling may produce a plastic or "liver-like" condition and the rolling should be discontinued where such a tendency appears.

18. Work Incidental to Grading.—Where it is a part of the contractor's work to reconstruct or readjust catch-basins, manholes, covers, and other structures, he should be required to keep this work done well in advance of the laying of the concrete foundation. If this work is delayed until after the main body of the concrete is in place, leaving openings to be filled later, hurriedly and perhaps carelessly, it may result in weak patches in the concrete around these structures, where, in fact, the concrete should be strongest.

CONCRETE FOUNDATIONS

19. The concrete foundation of a pavement is a most important part of the work, and must not be slighted in any way.

20. Quality of Materials.—The quality of the materials used for making the concrete are fully described in the specifications, and they must be substantially and uniformly adhered to.

The Portland cement delivered on the street will presumably have been previously inspected and accepted by the engineer, but any change in the kind, or brand, or apparent quality of the cement de-

livered after the beginning of the work should not be permitted without the approval of the engineer. Barrels or bags of cement not plainly marked with the brand, or name of the manufacturer must be rejected. You will frequently make balls of stiff mortar from the cement and sand used (1 part cement, 2 parts sand) and set them aside for observation. If in eight hours these balls do not set up hard the fact should be promptly reported to the engineer.

The sand and stone will naturally vary slightly from time to time, but should not differ materially from the requirements of the specifications or the standards adopted by the engineer. Stone or gravel that contains any considerable quantity, say more than 5%, of foreign matter, such as soil or refuse, should be rejected. Stone containing an excessive quantity of fine fragments or screenings bunched together in the pile, should be mixed with the mass of larger stone before it is used, so as to produce a mass of fairly even composition. Stone that is coated with mud, or that is not sound and hard should be thrown out.

Sand that is moderately coarse and does not contain more than 7 1/2% of clay or soil, and is free from vegetable refuse, may be used.

21. Storing Materials.—Cement stored on the street must be stacked up on dry lumber floors at least four inches from the ground and effectually covered to protect it from rain or snow. Packages of cement which, when turned out for use contain hard lumps should be rejected.

Sand and stone must be stored on tight lumber floors to prevent their admixture, when being shoveled up, with street soil or other impurities. This requirement must be enforced.

22. Proportioning Concrete.—The proportions of cement, sand and stone or gravel named in the specifications must be strictly adhered to.

A barrel of Portland cement will be considered as four cubic feet and a standard bag of cement as one cubic foot.

It is usual for the contractor to measure the sand and stone by wheelbarrow loads. In that case you will measure and determine the capacity, in cubic feet, of the convenient or average wheelbarrow load, and determine the size and number of loads each of sand and stone required for one batch of concrete (if made by hand) and thereafter see that the quantities thus determined are used, and the wheelbarrow loading uniform. To measure the contents of a wheelbarrow load, use a square box holding one cubic foot. It cannot be accurately measured on the barrow.

As a check upon the proportioning of materials, you should occasionally keep a record of the quantities of cement, sand and stone used for, say, one or two hours, and mark and measure up the quantity of concrete made with them, and from this data compute the ratios of the materials used. (In ordinary street concrete, proportioned 1 : 3 : 6, the volume of rammed concrete made will just about equal the volume of the stone used.)

Where the concrete is mixed by a machine with automatic feeding devices, reliance must not be placed upon the machine for proper proportioning. Frequent tests of the materials used and the volume of concrete turned out should be made as described above, and any necessary corrections made in the feeding devices of the machine. This test should be made daily if practicable. The eye will usually detect any material change in the composition of the concrete, and whenever such changes are observed the composition ought to be at once checked up by measurement.

23. Mixing Concrete.—See that the specifications are followed. Use sufficient water to make what is commonly called a wet concrete but not so wet that free water will drain from the mixed batch before ramming. The test for proper mixing will be that all the fragments of stone are completely covered with mortar.

24. Placing Concrete on Street.—All concrete must be placed and rammed before it begins to stiffen or set. Concrete should be so handled that the mortar will segregate or separate from the stone as little as possible. When in place on the street it should make a mass of uniform consistency and appearance. The concrete should, as soon as placed on the street, be graded to a proper thickness and surface, and then well compacted by ramming. Insist on good ramming; this part of the work is not often properly done. The surface of the concrete should be brought to the true grade by proper grading and tamping. Where necessary to raise the surface, additional concrete, made of small stone, may be applied during the tamping. Neat mortar should not be used for this purpose. Sweeping mortar over the surface with street brooms should not be permitted—it is useful only to cover up defects and to produce an extra smooth surface (which is not usually desirable). To measure the thickness of the bed of concrete, lay a straight-edge upon the surface with the end of the straight-edge projecting a foot or two beyond the edge of the concrete, and measure the space from the lower edge of the straight-edge down to the sub-foundation.

Care must be taken to finish the surface of the completed concrete

at the proper distance below and truly parallel to the grade and contour of the finished pavement. This is more important in the case of sheet asphalt pavements, since irregularities in the concrete will cause variation in the thickness of the finished asphalt surface, which will affect the durability of the pavement. The grade stakes for the concrete should therefore be carefully set and worked to, and humps or depressions between the stakes should be avoided.

25. In hot, dry, weather the concrete must be kept damp by watering it until it is at least five days old, and horse-travel over it must be prohibited until it has set up hard enough not to be injured thereby.

26. Old Paving Stone Foundations.—If a foundation is to be made of old paving stone blocks reset, the important points to be looked after are,

The preparation of the sub-foundation.

The sand bed.

The setting of the blocks.

The grouting of the blocks.

The sub-foundation should be prepared, where necessary, as stipulated in Sects. 16 and 17 of these instructions. This part of the work is likely to be carelessly done unless proper work is insisted upon.

The sand used as a cushion course must be of good quality and reasonably clean. The use of mixed sand and soil taken from the street excavation should not be permitted.

The blocks, after being cleaned from adhering dirt, should be set with reasonable care, well bedded in the sand cushion, and laid at such an elevation below the completed pavement surface, that after being well rammed, the surface will be at the proper elevation below the pavement datum.

The grouting of the joints is the most important part of the work. See that the mortar is made and used in accordance with the specifications, and that the joints are completely filled.

27. Broken Stone Foundations.—The specifications for broken stone foundations are sufficiently explicit, and compliance should be insisted upon. Thorough rolling is especially important.

SHEET ASPHALT PAVEMENTS

28. The manufacture of the mixture for sheet asphalt pavement, and the laying of it on the street, involve a number of separate elements or operations. The quality and durability of the pave-

ment will depend largely upon the skill, intelligence and accuracy with which each and all parts of the work are carried out. The inspector, both at the mixing plant and on the street, must give constant and intelligent attention to the work.

29. Inspecting at Paving Plant.—Inspectors at the plant where the asphalt paving mixture is made will be provided with the following apparatus:

1 nest of standard sieves, Nos. 10, 30, 50, 80, 100 and 200
2 thermometers for sand
1 tank thermometer
2 standard flow-plates and one dozen cartridges for same
1 balance for weighing sand
6 dishes, glass or porcelain, 4 inches in diameter.

30. The more important things for the Plant Inspector to watch during the manufacture of asphalt paving mixture are:

a. Quality and grading of the sand.
b. Temperature of heated sand.
c. Uniform quality of the refined asphalt and flux.
d. Temperature of melted bitumens.
e. Uniform consistency of asphaltic cement.
f. Correct ratios of sand and asphaltic cement.
g. Thorough mixing of materials.

31. Sand.—The general quality and grain-size of the sand, required by the specifications, must be closely watched and adhered to.

It is hardly ever possible to secure a natural sand that will conform strictly to the theoretical composition, but *substantial* compliance should be required unless the Chief Engineer directs otherwise. After any sand has been approved for a given contract or street, all the sand thereafter used for that street should conform closely to the standard so approved; for any material change in the quality of the sand will change the quality of the pavement produced, unless the proportions of the other materials are changed accordingly. Any material change in the sand should therefore be promptly reported to the Chief Engineer.

32. Sand for the sieve tests should be taken from the hot-sand box and allowed to become cold. From the sample thus taken, weigh out 50 grams. Arrange the nest of sieves with the No. 200 at the bottom followed by Nos. 100, No. 80, No. 50, No. 30 and No. 10 at the top.

Place the weighed sample upon the No. 10 sieve and thoroughly shake the nest until all the sand that will, has passed through the

various sieves; then weigh the various portions, beginning with that which has passed the No. 200 (deducting in each case the weight of the dish). The portion *remaining* on the No. 200, is the quantity *passing* the No. 100, etc. The sum of all these portions should be 50 grams, though it will usually be slightly less because of unavoidable waste. In use, keep the sieves clean and as free as possible from adhering grains by using a bristle brush.

33. Temperature of the Sand.—The temperature of the heated sand should be frequently noted by plunging the thermometer into the mass. It should not fall below 315° F. nor exceed 375° F. It is very important to avoid over-hot sand, because, in the mixer, the very thin films of bitumen covering the hot-sand grains are readily and quickly scorched by the excessive heat in the sand.

34. Refined Asphalt and Fluxing Oil.—Unless otherwise notified by the Chief Engineer you will assume that the stock of refined asphalt on hand at the beginning of the work has been inspected and is satisfactory. You will, however, note the appearance of the material and the character and marking of the barrels or packages, and will not permit the use of any new shipments of materials of different appearance or brand without authority from the Chief Engineer. The above instructions apply also to the oil used for fluxing.

35. Ratio of Asphalt and Flux.—You will frequently note and record the weight of asphalt and of flux used in charging the melting tanks.

36. Temperature in Melting Tanks.—The melting kettles are usually equipped with fixed thermometers, but their reading should be frequently checked with your detached tank thermometer. You will see that the temperatures in the kettles are kept within the limits named in the specifications. See that the melted asphaltic cement is kept constantly agitated as required by the specifications.

37. Uniformity of Asphaltic Cement.—It is very important that the asphaltic cement shall be of uniform composition and consistency, or hardness.

When the composition and consistency of the asphaltic cement to be used for the surface-course of any street has been determined upon and approved by the engineer, you will take out and preserve a sufficiently large quantity to be used thereafter as a standard, and each subsequent tank of cement, before it is used, should be tested by comparing it with this standard in the following manner, using the flow-plate apparatus:

Melt and fill two cartridges with the standard cement, and two with the cement to be tested, marking them for identification. When cold, carefully remove with a wetted dull knife any surplus cement from the ends of the cartridges so as to leave them exactly full and the metal ends clean. Immerse them in cold water until they are all of the same temperature. Then place and fasten these filled cartridges on the grooved plate with their lower ends exactly to the zero line on the plate, the standard samples alternating with the new. Then place the plate, at an inclination of about 45°, in front of a source of uniformly distributed heat, as, for instance, near a steam boiler or large steam pipe, or (when the weather is favorable) in the sunshine, facing the sun. Leave the plate in this position until the bitumen in the cartridges shall have melted and flowed down the grooves an average of from four to five inches. Then measure the lengths of flow of each from the zero line on the plate. If the average flow of the new samples differs more than 5 per cent. from that of the standards, the new cement should be regarded as unsatisfactory and should be corrected by adding more asphalt or flux, as may be required.

(If a *penetration apparatus* is supplied or is available, the penetration method may be used instead of this flow-method for determining the consistency of the cements. Proper instructions for its use will accompany the apparatus.)

38. **Ratio of Sand and Cement.**—When the proper ratio of sand and asphaltic cement has been determined for any street you will see that this ratio is carefully adhered to. The correctness of the weighing scales used should be frequently tested.

39. **Mixing.**—When the sand and asphaltic cement are properly mixed the appearance of the mass will be perfectly uniform throughout, with every grain of sand entirely and evenly coated with cement. The mixing should, however, be continued somewhat beyond the attainment of this condition, so as to insure thoroughness. After the proper result has been arrived at, either the *time* in the mixer, or the *number of revolutions* of the mixer shaft should be noted and the standard thus determined substantially adhered to thereafter. With the standard mixers commonly used, the hot sand and the filler (dust) should first be put into the mixer and mixed for about fifteen seconds; then the asphaltic cement added and the mixing continued as long as necessary (in the usual mixer not less than sixty seconds).

40. **Records.**—You will keep complete records of the results of

your observations and tests in a book which will be provided for the purpose, and will make such reports to the Engineer as he may direct.

41. Inspection on the Street.—The leading things to be kept in mind by the street inspector, in the laying of asphalt pavement on the street, are the following:

a. Temperature of mixtures when applied to the street.

b. Proper preparation of the street surface before material is laid.

c. Laying and rolling of the binder-course.

d. Laying of the surface-course.

e. Rolling the surface-course.

42. Inspector's Equipment.—The inspector will be supplied with the following apparatus:

1 armored thermometer reading from 200° F. to 500° F.
1 graduated spatula.
1 twelve-foot straight edge.
1 fifty-foot tape line.

43. Temperature of Mixture.—If proper care has been taken at the mixing plant the mixture will not arrive on the street at too high a temperature, and your principal care will be to see that it is not laid at too low a temperature. The minimum temperature named in the specifications should be adhered to. While the main or interior mass of a wagon load may be well above that temperature, the top and outer part of the load may be, particularly in cold weather, too cold to be safely used. Some of this colder portion may usually be sufficiently reheated by mixing it with the hotter material, if properly handled in unloading; but any material that is so cold as to be lumpy when unloaded, or, more particularly, when being raked out, should be discarded. This applies to both surface and binder mixtures.

It must not, however, be overlooked that the different kinds of asphalts have different appropriate working temperatures, and for some asphalts the minimum temperature named in the specifications may be too low. The best practical guide is the manner in which the mixture behaves in raking. It must always be so hot that it will, under the rake, break up into a uniform, crumbling or powdery mass. If it does not do this it is (unless the mixture is excessively rich in bitumen or improperly compounded) too cold.

44. Preparation of Street Surface.—Before the binder-course is laid, all loose material, rubbish, street dirt and other matter foreign to the concrete surface must be removed and the concrete surface

swept, if necessary, to properly clean it, with street brooms. Neither binder nor surface mixture shall be laid upon wet surfaces. Before the spreading of the surface mixture on the binder the latter must be cleaned of all foreign matter and, if necessary, swept. If the binder is covered with mud from wagons or other travel, the surface must be scrubbed clean. Any part of the binder-course that may have become broken or loosened before the surface-course is applied must be taken up and new material laid in its place with the same care as the original.

45. Laying Binder-course.—The binder mixture must be carefully spread and raked to such thickness that after being rolled it will present an even, true surface not varying more than one-fourth inch from the intended finished surface of the binder. The tendency is to lay the binder-course carelessly and to roll it insufficiently. Nearly the same care in raking and rolling as for the surface-course, should be insisted upon. If the binder is not thoroughly compressed before it becomes cold it is likely, in future hot weather, to soften and yield under heavy travel and thus to start depressions in the pavement which will increase with time.

46. Laying the Surface-course.—The requirements of the specifications should be rigidly enforced in the laying of the surface-course. Joints against a cold edge of previously laid surface must be cut back until solid, fully compressed material of full thickness is reached, and the raw edge completely but thinly painted with liquid paving cement or pitch. No masses or fragments of cold mixture, whether of binder or surface, must be allowed to remain on the surface of the binder in advance of the placing of the surface-course, to be covered up by the latter. Such cold masses will not be compressed by the roller, but will later, under a hot sun and heavy travel, yield and start depressions in the pavement. The raking out requires to be properly and skilfully done. The tines of the rakes must penetrate to the binder, so that the raked material will be a uniform mass from top to bottom.

47. Rolling.—You will insist upon the rollers being placed upon the freshly raked surface just as soon as the material will bear them without being squeezed out or displaced laterally. The tendency is to keep the rollers off too long, thus permitting the chilling of the surface and preventing its proper compression. Do not take the contractor's word as to how soon the rolling may be begun, but have trials made until you are able yourself to judge. The rolling by the heavy roller should be very thorough: keep the roller

at work constantly until the surface is too cold to be impressed. In operating the roller lengthwise of the street begin at the gutters and work toward the center of the street. Cross rolling and diagonal rolling must be insisted upon wherever the width of the street will permit it.

48. Proper Thickness and Surface.—While the completed surface is still warm enough to permit it, measure the thickness of the surface-course by forcing the graduated spatula through it to the binder and noting the depth of penetration. Also test the trueness of the finished surface with the straight-edge, and if found defective in either thickness of pavement or trueness of surface, insist on more careful grading and raking on the further work. Try the completed gutters with water to see that they are so truly laid that puddles of water will not stand in them.

49. Asphalt surface must not be laid when rain or snow is falling, or so long as the street surfaces are wet. Surface mixture raked out and caught in a shower before it is well enough rolled to exclude water must be taken up and discarded.

Unless unavoidable, neither binder nor surface should be laid when the street surface or the air is below 40° F. As a rule, the lower the temperature the of air the greater is the care necessary to properly lay asphalt pavement.

50. Measure each day the area of pavement laid and record that, and the quantity (number of batches) of surface mixture used, and note any lack of uniformity in the area laid per batch.

ASPHALT-BLOCK PAVEMENT

51. You may assume, unless otherwise instructed, that the Engineer has inspected and approved the general character of the blocks already delivered for the work, unless their inferiority be obvious, but you will be expected to observe them carefully as laid and to reject blocks that vary in dimensions from those permitted by the specifications, and those that are broken, disfigured or injured. But during the progress of the work you will note the character of subsequent deliveries and report to the Engineer any apparent change in the quality of the blocks.

The more important points to look after in the laying of the asphalt blocks are: the quality and grading of the mortar bed in which the blocks are set, and the care and accuracy of the block setting. The mortar must be of cement and sand in the ratios specified,

and sufficient water used to make a medium stiff mortar; the use of merely moistened powder must not be permitted; and any mortar that has begun to set up before the blocks are laid and rammed must be discarded.

52. In setting the blocks the principal requisites are: that they be well bedded in the mortar; that they be set so that after ramming their tops will be accurately in the pavement datum; that they be set and pressed as closely together as possible, levers or mauls being used to force them into close contact, both at ends and sides.

GRANITE-BLOCK PAVING

53. Assuming that the foundation has been properly constructed, the more important things for the inspector to look after are:

a. The quality and shape of the blocks.

b. The sand cushion.

c. The setting of the blocks.

d. The ramming of the blocks.

e. The filling of the joints.

54. The Blocks.—Assuming that the general *quality* of the granite has been approved, you will need only to observe and reject blocks made from soft or weathered or otherwise defective stone. Any material divergence of the blocks from the correct form or from the sizes specified as permissible will be readily caught by the eye as they are brought to the street, and they can then be thrown out. The proper dressing of the blocks is important and should be watched carefully. While you are not expected to examine each individual block, close observation of the blocks as they are handled and laid will enable you to detect and reject those that are materially defective in shape or dressing; or excessively wide joints will call attention to these defects as the blocks are set.

55. Sand Cushion.—The sand used for the cushion bed should be moderately coarse and must be fairly clean and pure. The tendency with contractors is to use any dirty sand or sandy loam available on the street. Such material, especially if it becomes filled with water, will yield under the blocks and will not support them properly. The sand bed should not vary materially in thickness. It should be laid and graded not more than fifty nor less than twenty feet in advance of the setting of the blocks.

56. Setting of the Blocks.—The blocks should be delivered in front of the block setters on the blocks already set. The blocks must be set in straight courses from curb to curb the courses running

at right angles to the street (except at street intersections). All the blocks in any one course must be of the same width. Each block should be so set that the whole of its bed will be seated upon sand. The usual practice of block setters is to make a bed by drawing the sand into a small ridge upon which the outer edge of the block is rested, its weight canting it against the course already laid. This usually leaves a cavity under the back edge of the block which neither the subsequent joint filling or ramming closes up, so that the block may rest permanently on only a part of its bed. The practice is so fixed with block setters that it will require firmness and persistency to prevent it, but you should insist that it be so modified as to give a solid bearing for each block over its whole base.

The blocks must be set solidly against each other so as to make the joints of the least possible width. Unless close attention is given to this the joints are likely to greatly exceed the width permitted by the specifications. Care should be taken that the blocks are set truly vertical so that their upper face shall be parallel to the plane of the street. In setting the blocks their straightest and truest face should be placed upward so as to make the surface of the pavement as smooth and even as possible. Block setters are often careless about this.

Ordinarily no grade stakes are set for the surface of the pavement and templates are seldom used, the block setters using only their eyes to make the surface conform to the intended contour of the street. This usually results in the completed street being more or less wavy and irregular, and in a lack of regular and uniform cross-section in different parts of the street, often very perceptible to the eye. Care should be taken to avoid this as much as possible. Straightedges and templates, cut to the proper curve for the surface, should be provided and used.

57. Ramming the Blocks.—This part of the work is likely to be slighted unless carefully watched. The important thing is to have each block equally and sufficiently rammed to bring it to a firm bearing on the sand, as well as to bring its top to the proper grade. The rammers will be disposed to touch lightly blocks or areas which if thoroughly rammed would be driven below the true surface of the pavement, and subsequent travel may force these down, making depressions in the surface. It is a very common practice for the men working the rammers to shirk on this work by allowing the rammers to fall with little more force than that due to their own weight. This should be detected and remedied.

58. Filling the Joints.—The specifications are quite full and clear regarding this part of the work and little further need be said.

Care is necessary, whether the joints be filled with gravel and bituminous cement or with grout, to secure the complete filling of all the joints. If the weather is cold at the time the work is done, the gravel filling may become so chilled before the bituminous cement is poured that it will not flow to the bottom of the joints. For this reason it is important that the cement be worked at the highest temperature that it will bear without injury.

If grout filling is used care is necessary to make the mortar of the right consistency. If too thick it will not flow freely to the bottom of the joint; if too thin its strength will be materially reduced. Experiments should be made to determine the proper consistency, and when this is found, the quantity of water used in making the mortar should be determined and thereafter measured out for each batch.

The mortar must be kept constantly stirred until used, otherwise the sand is likely to settle to the bottom. Whatever filling is used, a second and sometimes a third pouring will be necessary to completely fill the joints.

BRICK PAVEMENT

59. The matters requiring most attention in the construction of brick pavement (assuming that the foundation is in place) are the character and quality of the brick, the sand cushion, the setting of the brick, and the filling of the joints between the brick.

60. Inspecting the Brick.—The examination, testing and acceptance, in a general way, of the brick to be used for the work will be made in the engineer's office, and your duty will be confined in this matter to seeing that the brick delivered and used are in accordance with the standard established and the general requirements of the specifications. You can best inspect the brick as they are being laid or after they have been laid, and before the surface has been rammed or rolled. Presumably the brick-setters will discard most of the unsuitable brick during the progress of their work, particularly if they are given to understand distinctly the defects that will cause rejection.

As the setting is completed, go carefully over the surface of the pavement and mark plainly all the bricks that are to be removed for defects and see that all such are taken out and replaced with

good brick. The principal defects that should be observed are: soft or underburned bricks; those that are warped or deformed so that they will not fit closely to their neighbors, or have warped or ill-shaped tops; those that are broken or chipped or show injurious cracks, and those that are perceptibly wider or narrower than their neighbors in the same course.

Soft or underburned brick may be detected with most certainty by having the contractor wet the surface of the pavement by sprinkling. The soft brick will absorb more water and remain damp longer than the hard brick and can thus be readily detected. This test can be applied, however, only to pavements the joints of which are to be filled with grout, as bituminous filling should not be applied to brick with wet surfaces, and to wait until they become dry after the wetting would delay the work unwarrantably.

61. Sand Cushion.—See that the sand used is free from foreign matter and pebbles, as required by the specifications, and that the sand-bed is of uniform thickness, correctly gaged, and rolled to the true plane of the pavement, additional sand being added or surplus removed where necessary to secure this result. See that the cushion is not thereafter disturbed or, if disturbed, that it be restored to its original condition.

62. Setting the Brick.—The bricks are to be set as closely together as possible both at sides and ends, so that the joints will not be wider than permitted by the specifications. Where the bricks have lugs or letters on one side, the lug-sides shall in no case be laid together. The courses must be reasonably straight entirely across the street. See that the bricks in adjoining courses break joint not less than three inches. Brick-setters are likely to be careless about this. Do not permit bats to be used except where necessary at the ends of courses or to fit the pavement against street railroad rails or around manholes or other structures in the street, and insist that this filling in shall follow immediately after the brick-setting, and that close fits shall be made.

63. Rolling the Pavement Surface.—This should be carefully and uniformly done so as to insure the even surface and contour of the pavement. Do not allow the roller to make sharp turns on the freshly laid brick surface as it will disturb and cant the loose brick. The roller should run back onto the fully completed pavement to make any necessary turns or considerable changes of direction. Quick starts or stops of the roller on the fresh-laid brick should be avoided for the same reason.

64. Filling the Joints.—Whether grout or bituminous filling be used the important thing is to get all the joints completely filled. Where bituminous cement is used, if the work is done in very cool weather the brick is likely to chill the cement before it reaches the bottom of the joints unless the cement be applied as hot as possible without injuring it, and the pouring be rapidly and carefully done.

If grout filling be used, see that the mortar is made of the proper ratio of sand and cement and that it is of the proper consistency to just flow into the joints, and that after mixing it is kept stirred until used. Repour all joints where necessary to completely fill them.

65. Gutters and Expansion Joints.—See that the gutters are laid with longitudinal courses of brick and their joints filled with bituminous cement as provided in the specifications.

WOOD-BLOCK PAVEMENT

66. Foundation.—The instructions relating to the preparation of the sub-foundation and the concrete foundation already given apply to wood-block pavement.

67. Inspection of Blocks.—However carefully the lumber may have been inspected before its manufacture into blocks, the subsequent seasoning, treatment, handling and exposure to the weather will develop many defects and you will need to observe the delivered blocks closely, either before or after they are set, and reject those that do not comply with the specifications. The principal defects that you will be able to detect after the blocks are treated are the following: Southern pine blocks made of second-growth or inferior wood, partly shown by the number of annual-growth rings per inch. Blocks having a less number of these annual-growth rings per inch than is permitted by the specifications should be rejected. The treated blocks, especially when they are exposed to the weather for some time, are likely to develop seasoning cracks, "shakes" and loose knots, not observable in the lumber, and blocks showing these to an injurious extent should be rejected, though in many cases the defective part may be split off and the remainder of the block used for closers. If the blocks have become very dry and thoroughly seasoned out, they should be well sprinkled with water about twenty-four hours before they are to be set, to forestall excessive swelling and "humping" when a rain storm comes upon the new pavement.

68. Mortar Bed.—It is the common practice in preparing the mor-

tar for the mortar bed under the blocks to simply dampen the mixed sand and cement so that it may still be spread and handled like damp sand. See that sufficient water is used to make a moderately stiff mortar, suitable for being worked with a trowel. This mortar should be prepared in sufficiently small quantities at a time to insure that it will not begin to set before the blocks be placed in it and rammed.

69. Setting the Blocks.—The setting of the wooden blocks is a comparatively simple operation and the specifications are sufficiently full and clear for your guidance. See that the blocks are so set that their tops, after the ramming is completed, shall be truly in the pavement datum, without humps or depressions.

70. Filling the Joints.—See that the sand used is perfectly dry, fine and clean, and that it is swept about on the pavement until the joints are completely filled.

BITUMINOUS CONCRETE PAVEMENT

71. Preparation of Foundation.—Where a bituminous concrete wearing surface is to be placed upon an old pavement or Macadam road the specifications must be closely followed. A good foundation is as necessary, if good results are to be attained, as in the case of other pavements. The dressing down of high points and the filling up of depressions in the old pavement should be carefully done, so that the bituminous wearing surface shall be of uniform thickness, and shall be rigidly supported at all points.

72. Bituminous Concrete Surface.—The instructions given for the manufacture and laying of sheet asphalt pavement should be followed here insofar as they are applicable.

HYDRAULIC CONCRETE ROADWAY PAVEMENT

73. Like other structures made of hydraulic concrete, the utility and durability of concrete roadway pavement depends largely upon the good quality of the materials used and the skill and fidelity with which the work is done. It is especially important that the second, or surface, course of the concrete shall be made and placed in strict accordance with the specifications and that a high degree of *uniformity* shall be secured in the composition, consistency and workmanship of that part of the work.

74. Sub-foundation and Foundation.—The preparation of the sub-foundation will be the same as for other pavements, and the first, or

foundation course, of concrete, will be constructed as in the case of the concrete foundation for other pavements.

75. Material for Surface-course.—It may be assumed that, in general, the materials intended to be used on the work have been inspected and approved by the Engineer, but this should not prevent you from calling his attention to any defective or inferior materials that may be delivered on the street when the work is begun, or thereafter, and preventing the use of any materials that are not fully up to the requirements of the specifications.

76. Mixing the Surface Course.—See that the cement sand and stone are proportioned accurately and that the quantity of water used with each batch is measured, so as to make the concrete of uniform consistency. Do not permit any defective batches of concrete to be used in the surface course—if suitable for the bottom course they may be used in it. Care in this respect is particularly necessary with machine-mixed concrete where the machine is not working normally or the men operating it are careless or unskillful.

77. Placing Surface Course Concrete.—See that the surface course is placed, graded and rammed *before the bottom course concrete begins to set.* This is imperative. Also that the concrete is distributed and graded in such a way as will not separate or segregate the mortar from the stone; that the grading of the surface is so accurate that it will not be necessary later to add additional concrete to that already graded and rammed; that the ramming is thorough and uniform over the whole surface, and that the rolling is well done.

78. Expansion Joints.—Care should be taken to have the expansion joints made as the specifications require. See that they extend entirely through both courses of concrete; that the corners are properly compacted and troweled; that the joints are kept clean until they are filled with the bituminous cement, and are completely filled with the cement.

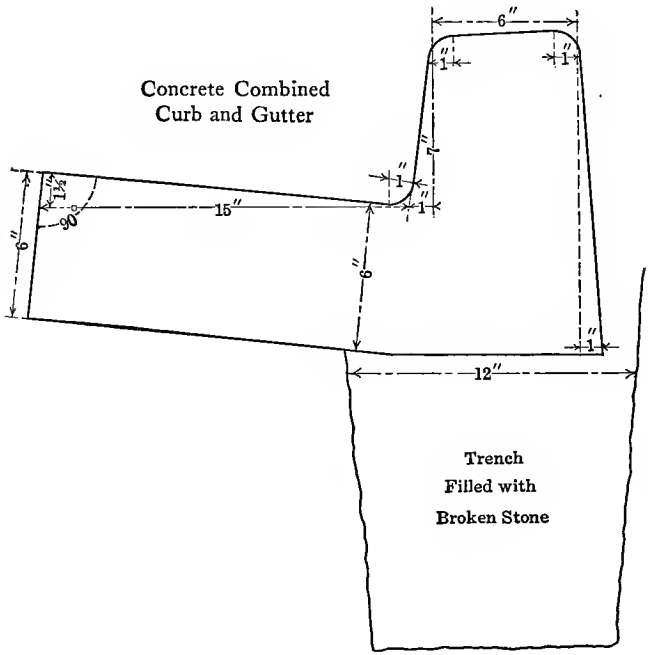
79. Care of Finished Work.—Do not permit the completed work to be disturbed by travel over it, and see that the concrete is kept moist, until it shall be set up hard, and that the street is not opened for travel until the engineer so directs.

CONCRETE COMBINED CURB AND GUTTER

80. General.—The specifications for the construction of Hydraulic Concrete Combined Curb and Gutter are quite full and clear and the

duty of the inspector will consist mainly in seeing that they are faithfully carried out.

81. Concrete.—As in other concrete construction, the utility of the work depends largely on the care and skill with which the concrete is made and placed. See that the prescribed quality and ratio of materials are used and that the concrete is thoroughly mixed and properly placed in the forms and well tamped. Especial care is necessary to secure a continuous and satisfactory exposed surface by forking and working the mortar into contact with the forms, which must be placed and maintained in true line and surface.



82. Removing Forms.—Good judgment is required as to the proper time to remove the forms. They must remain until the concrete has set hard enough to be fully self-sustaining, but before it has set so hard that the wire brush will have no effect on the surface.

83. Corner Protection.—See that the metallic corner or nose piece is correctly placed and that it is solidly anchored by and fully embedded in the body of the concrete.

84. Patching.—The practice of patching up cavities or irregularities in the exposed face of the curb and gutter with neat mortar, or dressing the surface with dry cement, must not be permitted. If a section of the curb is found, when the forms are removed, to be imperfect, the whole section must be removed and replaced.

HYDRAULIC CEMENT SIDEWALKS

85. General.—While the work of constructing concrete sidewalk is comparatively simple it is often carelessly and unskillfully done. The things that need most attention by the inspector are the following:

86. Materials.—The materials used in the work must be fully up to the quality called for by the specifications. This applies more particularly to the cement and sand. These are not always properly tested by the engineer and you should frequently make samples of stiff mortar (1 cement, 2 sand) and set them aside for observation. If they do not, in summer weather, become very hard at the end of nine hours, the fact should be reported to the engineer.

87. Drainage.—See that the necessary grading is properly done and that the drainage course is made of suitable material properly compacted. See that drain tiles are properly laid and connected as designed by the engineer. If cinders are used for the drainage course, see that they are screened to remove ashes and fine material, and that they are thoroughly drenched with water at least five days before they are placed in the walk.

88. Two-course Work.—If the sidewalk is laid in two courses, see that the surface-course is put on and tamped before the bottom-course concrete has begun to set. This requirement must be strictly enforced.

89. Finishing the Surface.—Dry or pure cement must not be used for trimming up or smoothing off the surface of the walk. After the surface has been properly completed by straight-edge and trowel, see that the wire broom is used as directed to remove the glaze and to slightly roughen the surface.

See that the expansion joints are made as specified, and that they extend entirely through both courses of concrete.

90. See that the walk, after completion is properly protected from injury and from frost, and that the concrete is kept moist until it becomes well set.